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2nd Edition – 2008

Treading on thin ice?

BBR's response to global warming and other topical themes

Optimising with BBR technology and expertise

Review of post-tensioned slab applications and advantages

Package deals in Poland

How the package approach has benefited clients in Eastern Europe

Energised for the future

Renaissance in the nuclear sector and BBR track record

Taking power to the people

MRR delivers solutions for all types of structure

THE MAGAZINE OF THE GLOBAL BBR NETWORK OF EXPERTS

A Global Network of Experts
www.bbrnetwork.com

BBR is recognised as the leading group of specialised engineering contractors in the field of post-tensioning, stay cable and related construction engineering. The innovation and technical excellence, brought together in 1944 by its three Swiss founders – Antonio Brandestini, Max Birkenmaier and Mirko Robin Ros – continues, more than 60 years later, in that same ethos and enterprising style.
From technical headquarters in Switzerland, the BBR Network reaches out around the globe and has at its disposal some of the most talented engineers, technicians and the very latest internationally approved technology in the world.

The Global BBR Network

Within the Global BBR Network, established traditions and strong local roots are combined with the latest thinking and leading edge technology. BBR grants each local BBR Network member access to the latest technical knowledge and resources – and facilitates the exchange of information on a broad scale and within international partnering alliances. Such global alliances and co-operations create local competitive advantages in dealing with, for example, efficient tendering, availability of specialists and specialised equipment or transfer of technical know-how.

Activities of the Network

All BBR Network members have established and strong local connections in their respective regions. They are all structured differently to suit the local market and offer a variety of construction services, in addition to the traditional core business of post-tensioning.

BBR Technologies

BBR technologies have been applied to a vast array of different structures – such as bridges, buildings, cryogenic LNG tanks, dams, marine structures, nuclear power stations, retaining walls, tanks/silos, towers, tunnels, wastewater treatment plants, water reservoirs and wind farms. The BBR brands and trademarks – CONA, BBRV, HiAm, DINA, SWIF ... and CONNAECT – are recognised worldwide.
The BBR Network has a track record of excellence and innovation – with thousands of structures built using BBR technologies. While BBR's history goes back over 60 years, the BBR Network is focused on constructing the future – established traditions are blended with the latest thinking and leading technology.

BBR VT International Ltd is the Technical Headquarters and Business Development Centre of the BBR Network, located in Switzerland. The Shareholders of BBR VT International Ltd are: BBR Holding Ltd (Switzerland); BBR Polska Sp. z.o.o. (Poland); BBR Pretensados y Técnicas Especiales, S.L. (Spain), member of the FCC Group (Spain); KB Spennteknikk AS (Norway), member of the KB Group (Norway); VORSPANN-TECHNIK GmbH & Co. KG (Austria / Germany), member of the Porr Group (Austria).

Through the pages of this, the second edition of CONNAECT, you will see that over the past year, the Global BBR Network of Experts has delivered leading edge solutions for some challenging projects. Very often, these have involved structures which affect the safety and well-being of the general population – we can all be confident and take pride in the knowledge that our people have provided the very best of the latest technology and know-how in their completion.

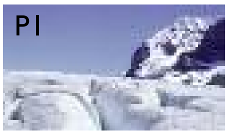
Without doubt, the commitment of our engineers to the development of new products has kept BBR ahead of the pack – and produced highly satisfied clients around the world. We are fortunate indeed to have some of the best qualified and most dedicated construction professionals working within the BBR Network. The glue that holds us all together and drives our success is excellent communication – we are constantly sharing information and knowledge.

The Global BBR Network is truly greater than the sum of its parts!

Bruno Valsangiacomo
Chairman
BBR VT International Ltd

Marcel Poser
CEO
BBR VT International Ltd

contents



Treading on thin ice? – An exploration of BBR's "green" product range, along with further news from within the BBR Network.

As the nuclear energy industry gears up for a revival, we examine the marketplace, as well as the products and expertise within the BBR Network.

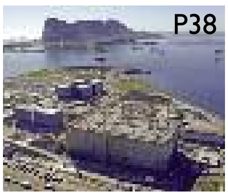
contents

continued

Review of the BBR CONA HiAm system – including a look at cable damping mitigation measures.

BUILDINGS continued

TANKS & SILOS



NUCLEAR ENERGY

STAY CABLES

MRR

BBR Contech's award-winning project strengthened power transmission towers in challenging terrain on New Zealand's South Island.

LANDMARK STRUCTURES

Treading on thin ice?

Whatever your personal beliefs about why global warming is happening – or whether indeed it is happening at all – there are some real benefits to be derived from adopting an environmentally sensitive approach. BBR VT International Ltd's CEO, Marcel Poser, outlines recent developments within the BBR Network which give the construction industry some greener options. ➔

What is absolutely clear is that there is no single means of halting climate change, so we need to explore all the options we have to reduce our environmental footprint, as we need to take care of our planet – because, so far, we only have one!

We have to change our attitude and abandon our fear that an environmentally sensitive approach means restrictions to our lifestyle. The fact is that taking a greener approach actually leads to innovation, business opportunities and continued growth. It is a challenge for our society and we need to work together. We need strong politicians, as well as sensitive and smart business leaders. Once clear and challenging targets have been set, mankind has always delivered. We flew to the moon, tore down the Iron Curtain … not because they were easy, but because they were hard and because there have been visionary leaders.

Narrowing our focus to the construction sector, it's simply not enough to rely only upon "sustainable technology" to fight the challenges of the future; we have to consider the entire lifecycle of a structure.

A good example in construction is the post-tensioning of slabs in buildings. PT slab tendons are the sustainable technology, but they only lead to a truly environmentally sensitive structure if we make smart choices from the beginning to the end - from the building placement, through integrated and customised building designs, to construction methods which fully exploit the benefits of the "sustainable" post-tensioning slab technology, as well as early stage re-usage and ultimate disposal considerations. If we do all of this, we not only end up with a structure which uses less concrete and steel, but have significantly reduced the carbon footprint and environmental impact during construction and have, in fact, also achieved a higher quality end product at a lower cost – thus, an environmentally sensitive structure which actually saves money! You can learn more about the benefits of PT slabs in the *Optimising with BBR technology and expertise* feature on Page 19.

One size FITS ALL?!

The one-size-fits-all concept is no longer a viable one for construction products – optimisation is needed to achieve the most environmentally-friendly structure. Opting to use post-tensioning means that a wider product range is available. For example, in days of old, you might have been working with multi-strand systems with four or five different sizes and you would have had to use a 31-strand anchor when, for the most economical solution, you actually needed a 24-strand anchor. BBR tendons are now grouped so that you only use what you actually need. All the size groups can be handled and stressed with just one piece of gear – the kit has been rationalised. In this way, we are helping to ensure that only the amount of anchoring material which is really needed goes into the structure, whilst minimising additional transportation impacts for construction gear.

In 2008, we are offering 25 different sizes of multi-strand anchorages – ranging from 1 to 61 strands. At the same time, our products will continue to promote faster construction programmes through early strength concrete stressing which reduces the construction cycle time – the earlier you can stress, the earlier you can build. Alternatively, a lower quality, cheaper or possibly recycled concrete can be used. One year on, BBR VT CONA CMI remains unmatched in offering early stage stressing.

BBR technologies also remain the benchmark for compactness in the anchor zone – even a year after introducing the new range of products. Our systems use the least amount of space in the anchor zone – again reducing materials.

European Testing of the BBR VT CONA CMI range has enabled the BBR Network to win a large number of jobs – in fact, the number of projects and product sales have exceeded our expectations.

Genuine Technology

Recently there's been much talk about counterfeit components – cheap copies of construction products which ultimately risk lives. There are indeed many "local" post-tensioning systems on the market which, despite some of them carrying our trademarks, actually bear no relation to the original, genuine BBR technology. Genuine BBR products are extensively tested according to the latest provisions, are based on over 60 years of experience and are constantly under surveillance by an independent auditor to ensure they continue to fulfil all the requirements of our European Technical Approval. There are now documents in the public domain, thanks to European Technical Approvals, which provide a real comparison with these copycat, look-alike and half-hearted copies. However, if you are in any doubt about a product which is offered, seek advice from the BBR Network.

MARKET RESPONSE

Over the past 12 to 24 months, we have truly felt the benefits of the BBR Network, a confederation of individual companies with their own strong local roots – and being the only company within the post-tensioning market place to have brand new and genuinely state-of-the-art products which are tested and approved to the European Technical Approval Guidelines (ETAG) and CE marked.

Since launching the BBR VT CONA CMX range last year, the response from the market place has been tremendous – and we are already now tackling the markets outside of Europe with our new product range.

ETAG and CE have become international benchmarks which have driven projects by BBR Network members that are now underway in the Middle East, Asia and Australia. This success can be attributed, in equal parts, to the expertise and excellent track record of BBR Network members, as well as the superiority of the products and their technical and environmental advantages. All of these qualities were well-publicised in 2007 - for example, during a road show to officially launch the products in Australia.

What's in a slogan?

"Nothing in this world can take the place of persistence. Talent will not; nothing is more common than unsuccessful people with talent. Genius will not; unrewarded genius is almost a proverb. Education will not; the world is full of educated derelicts. Persistence and determination alone are omnipotent. The slogan 'press on' has solved – and always will solve – the problems of the human race."

CALVIN COOLIDGE, 30TH PRESIDENT OF THE USA (1923-1929)

Have you ever wondered why, at BBR, we call our team a "Global Network of Experts"? It was – and remains – important to us that any slogan we use should reflect the qualities of our organisation – an international presence, our interconnection and positive working relationships and, above all, the attitude of our people. I believe that the BBR Network embodies the "Three Ps" – professionalism, persistence and pleasure – which go together to make a successful business. Professionalism is when organisations and individuals go the extra distance to develop and launch products or produce leading-edge project solutions. Have a look at the feature on Page 53 – *Taking power to the people.*

Next comes "Persistence" – this, for me, is about not giving up. For example, when testing something or finding the best solution for a project, you have to try more than once to find the right recipe – optimising and changing things as you go. Again, if you read the article on Page 37 *Special grouting operation,* you'll understand exactly what I mean.

Thirdly, we have "Pleasure" – the BBR Network can undoubtedly put smiles on faces. A key secret of the BBR Network is that we are in fact a family who respect each other as individuals and as professionals, have a desire to learn and enjoy working together – this is quite evident at all our meetings and indeed at our Global BBR Conferences.

Get plugged into the BBR Network!

If your credentials and aspirations match ours, we would very much like to hear from you – we are always looking for good, highly-qualified people and market-leading organisations to join the international BBR Network.

At BBR, we inspire our team members to improve themselves, both personally and professionally.

For further information, please contact us at careers@bbrnetwork.com, we would be pleased to hear from you.

2007 BBR PROJECT OF THE YEAR

At the 2007 BBR Conference in Singapore, BBR PTE (Spain) won the BBR Project of the Year Award for their excellent execution and innovation in post-tensioning for the Navia River Bridge, in Asturias, in northern Spain.
The bridge's most striking characteristics are the two 160m central spans held up by two arches.

The Navia River Bridge project convinced the jury because of the wide range of BBR post-tensioning systems that were used – stay cables, internal and external prestressing (massive 42 strand tendons) and bars. In addition, the project team used BBR heavy lifting strand jacks and BBR auto-propelled robots to place the jacks inside the deck.

Global BBR conference 2008

This year, we are looking forward to seeing the whole BBR family together in Sydney. There will be a number of presentations and BBR technology updates, but it will not be all about work. We have planned a number of social events too – including a Charity Golf Tournament. The Conference will reach it's climax with a formal dinner – during which the winner of the 2008 BBR Project of the Year Award will be announced. Then, the BBR Network will return to their work – revitalised and ready to deal with upcoming challenges.

OUTLOOK

Over the next 12 months, we expect to be harvesting the fruits of our labours – with some additional product launches within the BBR VT CONA CMX series. These products will be larger sizes – including world record-sized multi-strand tendons which will be used in the nuclear industry. We have new products for external post-tensioning and will be launching a proprietary product mainly geared for strengthening structures.

As far as the market place is concerned, we anticipate that the energy sector will continue to perform strongly in 2008 and beyond. We are also looking forward to exciting cable stayed bridge projects which typcially feature cross-continental BBR Network collaboration – more of that in the next edition!

Finally, we have also grown as a Network and I'd like to welcome some new faces who have joined us – check out the penultimate pages to discover where!

KULMBACHTAL BRIDGE, NEAR NABBURG, GERMANY

First use of BBR VT CONA CMI

Thanks to their use of the BBR VT CONA CMI and BBR VT CONA CMB prestressing systems, Dipl.-Ing. Thomas Weber of BBR Network member **VORSPANN-TECHNIK GmbH** reports that, at the end of 2005, his company received a major order. Their commission is to carry out all the prestressing work for the largest of nine bridges on the A6 motorway widening project, between the Amberg-Ost junction and interchange at Oberpfälzer Wald, in Germany.

The A6 motorway runs in an East-West direction – from Waidhaus on the German-Czech border, to Saarbrücken on the German-French border. It is part of the international East-West axis – the E50 European Highway – which connects Paris with Prague. The construction of the Kulmbachtal Bridge took place as part of the project to close the gap in the A6 between Amberg and the interchange at Oberpfälzer Wald. The bridge represents an important milestone for Germany within the context of the expansion of this vital axis – which is becoming increasingly more important with the enlargement of the EU in an easterly direction.

CONSTRUCTION DATA AND METHOD

The Kulmbachtal Bridge consists of a single prestressed concrete box girder via nine spans with a maximum span of 62m, for each carriageway. The overall length between the north and south abutments is 515m. The maximum height of the bridge above the valley floor is 32m. The two superstructures are being built using the incremental launching method in weekly cycles of 17 sections each. The standard section length is 31m.

PRESTRESSING CONCEPT

The superstructures are being constructed by the so-called "hybrid construction method" – using BBR VT CONA CMI 1506 – 150 1770 post-tensioned prestressing tendons for the centric prestressing. Up to 22 tendons are used in the carriageway slab, while in the bottom slab up to 10 tendons are being placed – all run over two sections and 50% of the tendons are anchored at the section joints. In the spans with the largest distance between supports, two additional tendons of the same type are arranged in the bottom slab – these are, however, shot in and stressed via pilaster strips after the final launching.

Section joint with BBR VT CONA CMI 1506 fixed couplers and overlapping prestressing tendons.

The higher permissible prestressing forces, as set out in the new DIN 1045-1 national standard, were already envisaged during construction planning ($P_{0,max} = 0,9 \times f_{p0,1,k}$). Due to the existing carriageway slab thickness of only 48cm, combined with the large number of tendons, it was of the utmost importance that the prestressing system selected should have as small as possible centre spacings and edge distances from the tendon anchorages. In addition, the minimum concrete strength at the time of stressing had to be as low as possible in order to achieve the weekly construction cycle. A minimum concrete strength of 30N/mm^2 was targeted and finally agreed.

CLEARING THE WAY

In order to fulfil these requirements, VORSPANN-TECHNIK used the European Approved BBR VT CONA CMI post-tensioning system. In fact, the first use worldwide of the BBR VT CONA CMI prestressing system – with its ground-breaking technological advantages.

For the eccentric prestressing, the BBR VT CONA CMB 1606 – 150 1770 band system is being used. The tendons are deviated with PE saddles at the support cross beams and the span pilaster strips. For each bar, three tendon strands run via the complete bridge length, with a maximum tendon length of 220m. The tendons are each prestressed, on both sides, at the anchorages fixed in the final cross beams and span pilaster strips. The installation and the prestressing of the external tendons is done after the final launching of the corresponding superstructure.

External prestressing tendons – in the foreground, span pilaster strip with curvatures and anchorages and, in the background, cross support with curvatures.

TEAM & TECHNOLOGY

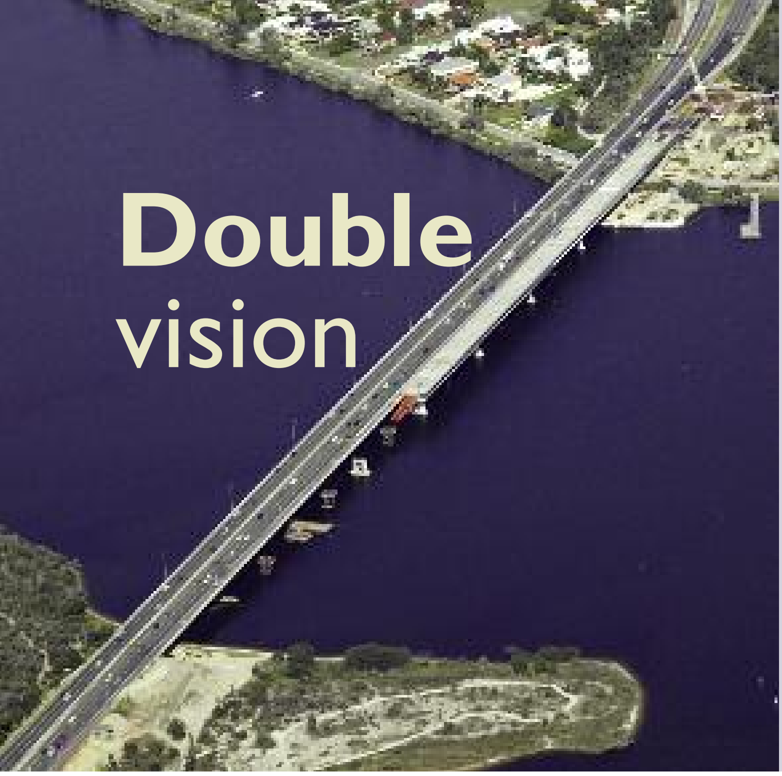
OWNER
Federal Republic of Germany, represented by Autobahndirektion Nordbayern (Motorway Administration Office of Northern Bavaria)

CONTRACTOR
DYWIDAG Bau GmbH

DESIGNER
Leonhardt, Andrä und Partner, Nuremberg

TECHNOLOGY
BBR VT CONA CMI internal
BBR VT CONA CMB band system

BBR NETWORK MEMBER
VORSPANN-TECHNIK GmbH (Germany)



Double vision

As part of the New Metro Rail Project connecting Perth to Mandurah, the existing Mt Henry Bridge across the Canning River on the Kwinana Freeway needed to be widened, or duplicated, to take the two new rail lines, reports Hudson Lun of STRUCTURAL SYSTEMS LIMITED, the Australian BBR Network member.

The city of Perth in Western Australia boasted a world class light rail link from the City central business district northwards to the satellite city of Joondalup, situated within the centre corridor of the city's Mitchell Freeway. However, Perth had no rail link in a southerly direction within the corresponding Kwinana Freeway.

Out of this urban transport need was born the New Metro Rail Project which would eventually provide the missing rail link southwards from Perth to the satellite city of Mandurah some 100km to the south.

BRIDGING THE GAP

The existing Mt Henry Bridge was constructed in the 1970s and

The 36m high Rascane Viaduct, where **BBR CONEX** is supplying leading edge post-tensioning services, spans the most challenging terrain on the Zagvozd to Ravca section of the Zagreb motorway and cuts through the mountains, giving magnificent views of Biokovo Nature Park.

THE RASCANE VIADUCT, CROATIA

Croatia's largest construction project

The difficult terrain and considerable incline of the ground drove the decision to construct the viaduct using the incremental launching method. The viaduct is a 633m long, 19-span, box girder road bridge – with a downhill slope of 4%. End spans are 26m long and 17 of the middle spans are 33m long.

SEGMENT PRESTRESSING

Prestressing of segments is being carried out by BBR CONEX. A 2.8m high box girder cross-section is prestressed with BBR VT CONA CMI internal post-tensioning technology, in a single stage, for all the loads – including traffic. Launching is performed in a downhill direction and the total weight of the structure to be launched is 13,000t.

REPETITION REDUCES COSTS

On the top of each pier, a guiding system has been installed which consists of two steel structures positioned on both sides and is helping to guide the structure whilst allowing for small deviations. Formwork is being reused many times – the regular repetition of identical tasks for the construction of each of the segments substantially reduces the ratio of labour-to-material costs.

TRANSFERRING FORCES

The casting yard bears a horizontal force of a total of 1200t – generated by the jacking equipment during launching – and to transfer this massive force to the ground BBR CONEX has also provided geotechnical anchors.

OPTIMISED METHOD

The use of relatively long 33m segments is very economical because of the straight tendon layout and reduced number of joints in the structure. In addition, the casting cycle is optimised in a week-by-week rhythm which is a particular benefit of using the incremental launching method.

The Zagvozd – Ravca section of the motorway is expected to open for traffic during 2008.

TEAM & TECHNOLOGY

OWNER
Hrvatske Autoceste (Croatian Motorways)

CONTRACTOR
Osijek Koteks, Osijek / Palmir, Zagreb

DESIGNER
Kresimir Ilic (IPZ, Zagreb)

TECHNOLOGY
BBR VT CONA CMI internal

BBR NETWORK MEMBER
BBR CONEX (Croatia)

carried six lanes of freeway traffic, with three lanes in each direction. It was a post-tensioned double box concrete girder type bridge, originally built using pre-cast segments assembled on a supported steel truss and then stressed together.

Following extensive analysis, it was decided to construct a separate bridge alongside the existing bridge to carry northbound traffic – and to strengthen the existing structure to take both the southbound traffic and the new rail lines. However, this new bridge would be virtually touching the existing bridge and, to the casual observer, would appear to be simply a widening of the original bridge.

INCREMENTAL SOLUTION

The final design was a single box concrete girder with large underside flanges to carry pedestrian and service traffic. The method of construction chosen was an incrementally launched solution to provide the least disruption and the quickest possible construction period. Leighton Contractors employed Structural Systems to supply and install the post-tensioning works in addition to the hire and operation of the incremental launching system, including temporary bearings and side guides. The existing bridge actually served as the main side guide for the launching process.

VITAL STATISTICS

The large 76m spans required the use of temporary piers during the launching process. The 660m long structure comprised 28 segments, each typically 25m to 28m long, and contained over 400t of 15.2mm strand. Tendon sizes varied from 5 strands to 31 strands. Structural Systems also supplied and installed stress bars for the external strengthening works on the existing bridge.

Speedy construction

VIADUCT OVER NALON RIVER, ASTURIAS, SPAIN

Guillermo Molins Roger of **BBR Pretensados y Técnicas Especiales** describes the construction of this remarkable bridge which forms part of the regional AS-17 highway running between Avilés and Puerto de Tarna in the Principality of Asturias, Spain. The road passes through a narrow corridor and, as a result, several structures are needed in a relatively short distance – the most important of these is the double viaduct over the Nalon River.

It is a composite bridge in two directions – longitudinally and cross-wise – and has spans of 27.5m, 110m and 27.5m. The end spans are of concrete box construction, while the central main span was constructed as a steel beam with a concrete slab above. With this combination, a huge span and fast installation time were achieved.

BBR PTE was involved in this construction project right from the design stage – leading Spanish design practice, IDEAM, designed the structure using BBR systems. The BBR CONA external system was chosen to provide a joint longitudinally between the concrete end section and the central steel section.

The tendons which join the steel structure to the concrete boxes have a combination duct. It begins in the abutments with a steel strip duct, then the material changes from steel to HDPE ducting whilst still inside the concrete, so that when the tendon emerges from the concrete, it is protected by the corrosion-free HDPE duct.

The concrete end spans were post-tensioned with BBR CONA internal 2406. The steel section was joined to the concrete ends by BBR CONA external 2406 tendons.

Stressing of all the tendon pairs (with cross symmetry) was carried out symmetrically and simultaneously using two jacks. Some tendons were stressed from inside of the concrete box. The anchor for these tendons was placed in the angle between the lateral walls and the upper slab of the box. A special hanging tool was designed to operate the jack.

TEAM & TECHNOLOGY

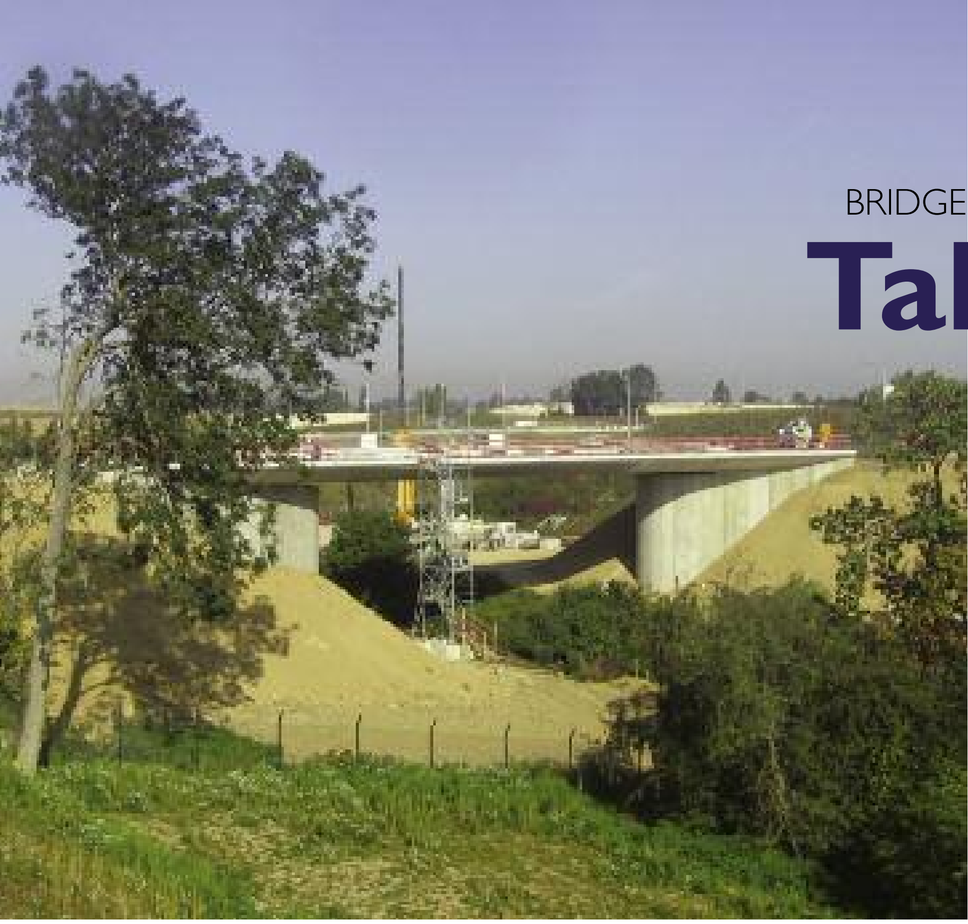
OWNER
Principado de Asturias

CONTRACTOR
J.V. FCC CONSTRUCCION, S.A. + ALVARGONZALEZ

DESIGNER
IDEAM

TECHNOLOGY
BBR CONA internal + external

BBR NETWORK MEMBER
BBR PTE (Spain)



BRIDGES K33A & K35A, ROISSY, FRANCE

Taking flight

Bridge K35A will serve the new terminal at Roissy Charles-de-Gaulle Airport.

A new Terminal – T2G – at Roissy Charles-de-Gaulle Airport is due to come into service during autumn 2008 to handle flights operated by Air France's three regional subsidiaries, Brit Air, City Jet and Régional. BBR Network member, **ETIC,** has provided post-tensioning technology and know-how for the construction of two bridges, one of which will be the principal vehicle access for passengers to the new terminal. Both bridges have been designed by the client organisation, ADP (Aéroport de Paris) and are well on target for completion.

BRIDGE K33A

Bridge K35A is 48.2m long and 0.75m thick, with a total width of 16m. The two spans are supported from one central pier which has been designed with five special 310mm diameter metallic bars and a spherical bearing on the top to assure the connection with the slab. The pier is anchored on the foundations by tensioned bars which are protected by wax.

The abutments consist of concrete pier caps with transversal post-tensioning and one additional short slab.

BRIDGE K35A

Bridge K35A has one 37.6m long span which is 1.3m thick. The cross-section consists of a section of concrete which is 7.10m wide in the middle of the span and 9.10m wide on the abutments. The width of the total cross-section, including the lateral cornices, is 15m.

TEAM & TECHNOLOGY

OWNER/DESIGNER
ADP (Aéroport de Paris)

CONTRACTOR
RAZEL Grands Chantiers

CONSULTANT
JV Prodétis and IOA

TECHNOLOGY
BBR VT CONA CMI internal

BBR NETWORK MEMBER
ETIC (France)

The A2 South Motorway in the Austrian province of Carinthia was built in the early 1980s, since when the traffic on this route has quadrupled and, looking to the future, a further increase must be expected. The motorway has now been widened to meet this increased demand – the scheme includes the construction of additional bridges alongside existing ones. Rudolf Vierthaler of Salzburg-based **VORSPANN-TECHNIK GmbH & Co. KG,** the Austrian BBR Network member, presents details of the erection of the second structure at bridge P19, focussing on the post-tensioning concept. →

THINKING **AHEAD**

LAVANT BRIDGE,
A2 SOUTH MOTORWAY, AUSTRIA

The existing structure of bridge P19 has main spans of 74m, 146m, 160m, 160m, 155m and 85m – making a total length of 780m. There are four side spans of 43.5m and one of 38m, totalling 299m. The height of the box girder is 9.5m on top of the piers and 3.8m in midspan. The elevation of the bridge deck is about 160m above the valley floor.

The main spans were erected between 1981 and 1984, by Steiner Bau GmbH, as a concrete structure cast in situ using the free cantilever method, while the side spans were constructed by incremental launching. Post-tensioning was provided by 540t of VT 16-100 internal bonded tendons.

NEW SECOND STRUCTURE

The second structure was completed in 2007 by the same contractor and the main spans follow the contours of the first bridge – and were also built using the free cantilever method and cast in situ.

The side spans of the second structure are 58m, 52m and 45m and have been built as a steel-concrete composite structure.

POST-TENSIONING CONCEPT

For the post-tensioning of the main spans, a modern concept was implemented.

The tendons for the negative moments of the free cantilever are VT 12-150 internal bonded tendons, with plastic ducts to meet the crack-width limitation regulations. For the final dead

loads and for the live loads, BBR VT CONA CMB 1606-150 1770 external tendons have been used.

The band tendons, originally invented by VT Austria, consist of bands with four 0.62" diameter strands. The strands are individually greased and covered with one extruded layer of 2mm HDPE and a second HDPE layer 3mm thick in a rectangular shape. The ultimate strength of such a band with four strands is 1.062kN.

"THANKS TO MODERN DESIGN, RELIABLE POST-TENSIONING SYSTEMS – AND EXCELLENT CRAFTSMANSHIP – A VERY HIGHLY DURABLE STRUCTURE IS EXPECTED."

In this particular case, four bands are stapled on top of each other, to form a tendon with a permissible stressing force of 2.974kN at $0.7f_{pK}$.

TENDON LAYOUT

The internal tendons are located in the deck slab (up to 54 units) and in the bottom slab (up to 6 units) only, which allows easy concrete pouring for the webs and, thus, ensures sound concrete quality.

The external post-tensioning is achieved with 12 BBR VT CONA CMB 1606-150 1770 tendons, with an average length of 221m. Facilities for the possible future strengthening of the bridge have been incorporated now, by making space for an additional eight external tendons.

The tendons are guided by deviator saddles in the middle of the spans and at the pier sections. The saddles are curved polyethylene boxes, produced by the CAD-CAM method.

ENDURING STRUCTURE

The tendon layout concept has minimised the risk of problems with pouring and compacting of the concrete. The external tendons can be inspected easily and, in case of any defect, they can be replaced in live traffic – and additional tendons can be added, if necessary.

Thanks to modern design, reliable post-tensioning systems – and excellent craftsmanship – a very highly durable structure is expected.

TEAM & TECHNOLOGY

OWNER
Country of Carinthia Bridge Department, on behalf of ASFINAG

CONTRACTOR
Steiner Bau GmbH, St. Paul / Lavanttal

DESIGNER
Ertl, Horn & Partner, Klagenfurt / FCP, Vienna / A. Pauser, Vienna

TECHNOLOGY
VT internal
BBR VT CONA CMB band system

BBR NETWORK MEMBER
VORSPANN-TECHNIK GmbH & Co. KG (Austria)

Package deals in Poland

The extensive scope of works, for the construction of the Warta Bridge, with which **BBR Polska** has been entrusted is a great example of a "package deal" – that is, an arrangement convenient to all parties involved. Such a one-stop-shop approach offers single-point responsibility for a range of construction services and helps the client manage the overall project more effectively – as well as attracting cost and programme benefits.

Today, the arches of the Warta Bridge, near Gorzów Wielkopolski, project a thin line against the sky – a simple, elegant silhouette. One has to realise the actual dimensions of the bridge – a length of 708m – to understand that this lightness is just a visual effect – in reality, we are looking at a robust structure which makes the hangers look like threads.

BBR Polska's work for this project included the supply of 32 pot bearings; supply and installation of expansion joints; incremental launching of the steel bridge superstructure; and the supply, installation and adjustment of the hangers The five-gap modular joint is the largest one ever assembled and installed by BBR Polska. It was manufactured in BBR's own workshop.

FIRST IN POLAND

The most recent package deal – a project which is not yet completed – brings BBR Polska back to the landscape where their activity started, some thirteen years ago – the mountains! The road bridge under construction crosses the Dunajec River in Brezna and forms part of the Stary Sàcz Bypass.

The three-span bridge (77.92m, 143m and 77.92m) is a continuous beam structure, with pylons placed on the intermediate supports. Six pairs of diagonal stay cables are anchored at the top of each of the pylons, which tower 18.47m over the deck. The beam consists of two concrete decks – upper and lower decks – which are connected by two steel pipe trusses. This type of structure is being used for the first time in Poland. ➔

Launch process

The launching process was undertaken in two phases:

- **Section 1, between piers 1 and 7** (starting from pier 1) - total weight of the structure shifted was 4,200t
- **Section 2, between piers 7 and 13** (starting from pier 13) - total weight of the structure shifted was 3,240t

It took seven launching cycles to complete the whole operation. For Section 1, the structure was launched together with the steel arch. The hangers were fixed in the steel arch structure before the seventh launching cycle started. On completion of the launching process, the support of the main span – the bottom fork anchors of the hangers – were fixed in place. The final adjustment was made after the deck had been completed.

"THESE TWO FLYOVERS – WHICH INCLUDE POLAND'S LONGEST ONE AT 730M LONG – FORM THE LARGEST INTERCHANGE ON THE SIEKIERKOWSKA ROUTE."

The construction is also being carried out by the incremental launching method. The bridge superstructure has 13 sections – not counting the pylons – to be launched, making a total weight of 6070t, including the 50t launching nose.
BBR Polska has been entrusted not only with prestressing of the bridge structure, but also with the supply and installation pot bearings and expansion joints; supply of materials and execution of the bridge structure's suspension; and the supply of equipment and services – and execution of the incremental launching operation.

WARSAW FLYOVERS

Another project, carried out by BBR Polska as a package arrangement, makes a dramatic statement on the city landscape of Warsaw – the two main flyovers of the three level Mars Junction. These two flyovers – which include Poland's longest one at 730m long – form the largest interchange on the Siekierkowska Route.

The works contracted to BBR Polska included detail design; supply and installation of 54 bearings; prestressing of the superstructure – one of the flyovers is also transversely prestressed with 64 50mm diameter prestressing bars; supply and installation of multi-modular expansion joints. BBR Polska also adapted the construction method, relating to the cable layout, to take into consideration the changed sequence of span execution and the characteristics of the BBR prestressing system.
Both flyovers were built by the "span-by-span" method on scaffold – but, for the flyover curved on plan, construction took place from both sides.
The long and frosty winter of 2006/2007 did not significantly affect the construction schedule and the completed crossing was opened to traffic in June 2007.

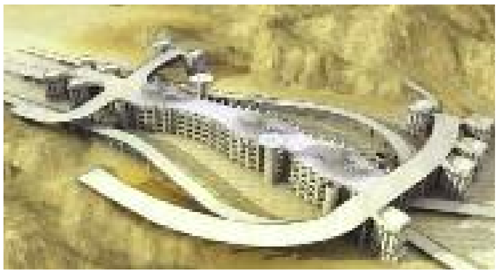
WELL-ROUNDED PACKAGE

Package deals are the goal we aim for, as they benefit everyone. For the subcontractor, it is obviously convenient to carry out the whole range of activities within one project, as it enables long-term planning and effective resource management – of personnel, materials and equipment. While for the owner and the contractor, it is certainly easier to co-ordinate the various operations with just one team providing a range of services – rather than with several different organisations, each providing one element.

PLACE for pilgrims

JAMARAT BRIDGE ACCESS RAMPS, SAUDI ARABIA

The increasing number of pilgrims has dictated the continuous need to develop infrastructure to and around the Islamic holy places in the Kingdom of Saudi Arabia. One of these places is the Jamarat site, where at least three million worshippers have to be present, once a year, in a single daylight period.



In order to solve the difficulties associated with hosting such a large gathering of people, the Government of Saudi Arabia initiated a new design for a multi-story structure which creates more space and additional areas that will more easily facilitate the casting pebbles supplication and the movement of the pilgrims.

The project also has many features which will significantly improve emergency access and evacuation, as well as providing much better services, generally, in a comfortable environment. The main structure – a precast segmental bridge – consists of four floors of approximately 600m long, 12m high and widths ranging between 60m to 97m. In addition, there are access ramps – consisting of precast, prestressed T-beams – covering a total area of approximately 180,000m^2 – to the different levels of the main structure.

Huta Hegerfeld Saudia Ltd was contracted to construct the access ramps in their entirety. This is an excellent example of co-operation between two BBR Network members – Huta Hegerfeld BBR Prestressing Division, Saudi Arabia and Marwan Al Kurdi & Partners Co. Ltd, Jordan – which has resulted in a very successful performance.

SIGNIFICANCE OF JAMARAT

Worshippers come to the Jamarat site in Mina as part of the annual Hajj pilgrimage – to the Islamic holy city of Mecca – during which a number of rituals must be performed. Once at the Jamarat site, they hurl pebbles at three stone walls. "Jamarat" literally means "stone pillars" in Arabic – however, the pillars at the Jamarat site were replaced with walls, following the 2004 Hajj during which over 500 pilgrims were either killed or injured. The ritual act – where seven stones are thrown at the pillars in a prescribed sequence over a three day period – represents the stoning of the devil by the Prophet Abraham.

TEAM & TECHNOLOGY

OWNER
Ministry of Municipal and Rural Affairs

MAIN CONTRACTOR
Saudi Binladin Group

DESIGNER
Dar Al-Handasah (Shair and partners)

TECHNOLOGY
BBR CONA internal

BBR NETWORK MEMBERS
HUTA/BBR Prestressing Division (Saudi Arabia)
Marwan Al Kurdi & Partners Co. Ltd. (Jordan)


Imaginative

Lawrence Hargrave Drive is a spectacular section of coast road, just north of Wollongong in New South Wales. Between Clifton and Coalcliff, this road had a long history of geotechnical instability, resulting in road closures, sometimes for months at a time. Many attempts were made to maintain the road in an open condition – none with long term success. Former principal engineer on the project, Mark Sinclair from BBR Network member **Structural Systems Limited** tells of the Alliance which was formed and the imaginative structure which emerged – to the east of the original alignment and, in places, in the Pacific Ocean.

The new structure – now known as Sea Cliff Bridge – consists of a five span, 450m long balanced cantilever bridge adjoining a seven span, 203m long incrementally launched bridge, both sharing a common pier. The bridges incorporate two traffic lanes of 3.5m to 3.8m wide, with 2m by 1m wide shoulders and a 2.5m shared pathway on the eastern side. The goals of this ambitious project were to provide a fully available road with a design life of 100 years.

IMAGINATIVE ALLIANCE

In a "first" for the Roads and Traffic Authority (RTA) of NSW, the LHD Link Alliance was formed between RTA, Barclay Mowlem Construction Limited, Maunsell Australia and Coffey Geosciences. Structural Systems' role in the project was the provision of the incremental launching technology.

DESIGN CONCEPT

The concept of a double "T" incrementally launched bridge, was adopted from the outset for the northern structure, while a balanced cantilever structure was chosen for the main southern structure – given the 108m central spans, which enabled the foundations to fit on the few available areas but could still follow the road's necessary geometry. Although this is a rarely built type of structure in Australia, the technology is well-established and was a suitable solution to the site constraints.

FORMWORK TRAVELLERS

In order to construct the balanced cantilever bridge, formwork travellers needed to be procured. Two second hand pairs were sourced which had just completed a bridge in Slovenia, and which had a 6.0m wide main box. The initial bridge design was with a 6.5m box, but was changed to 6.0m to minimise the modifications to the travellers.

Considerable refinement and evolution also occurred with the pile caps, which changed from a hexagonal to rectangular shape for the balanced cantilever bridge, saving material and enabling simpler construction.

PIER HEAD CONSTRUCTION

Pier head construction for the balanced cantilever bridge involved the casting of a 6.2m long section centrally over each pier. A large 15.4m by 12.5m four module working platform was attached to each pier to allow for construction. Three pours of 25m^3, 50m^3 and 25m^3, were necessary to each pierhead, for the base, walls and deck slab.

A large 15.4m by 12.5m four module working platform was attached to each pier to allow for construction.

Closure pours utilised a series of additional systems – including a small travelling system and special formwork.

For incremental launching, a kinked 30t launch nose was fitted to reduce the bending moments and deflections.

The travellers were assembled in a back-to-back pair arrangement on each completed pierhead for the first north and south segment pours.

After completion of cantilevering, the travellers were "back launched" to the pier for disassembly and relocation to the next piers.

ALLIANCE

The travellers were assembled in a back-to-back pair arrangement on each completed pierhead for the first north and south segment pours. Each pier required 10 segments of 4.95m – cast both on the north and south sides. The deliberate sequencing was that the north segment was cast then stressed prior to the casting of the opposing segment.

Each of the four travellers, once fully operational, could complete a 4.95m segment per week. As there was no 50% segment offset in the pier head, a maximum of one segment was out of balance during cantilevering. In order to offset the moment effects, the deck had kentledge applied at critical times on the southern side of the pier.

The road geometry dictated varying horizontal radii – straight, 350m and 500m. Segments were precambered to accommodate deflections within the traveller and the cantilever loading. The closure pours on the balanced cantilever bridge were generally 2.8m internally and up to 9.4m at the south abutment and 8.6m at the pier 7 interface. These were built by a series of systems, a small travelling system for the southern and northern closures, special formwork for the span 2 closure and the traveller for the closures to spans 3 and 4.

INCREMENTAL LAUNCHING

The incrementally launched bridge was constructed at the northern abutment and launched south over piers 1 though to 7. A kinked 30t launch nose was fitted to reduce the bending moments and deflections.

The spans were six by 30m, plus an abutment span of 22.8m. The first segment was 8.255m long, with the subsequent 13 being 15m long each.

The entire structure is on a constant 150m plan radius, 3% crossfall and 2.531% longitudinal gradient. As a double "T" structure, strengthening diaphragms were added at each pier location and the abutment.

An hydraulically operated casting mould formed each segment, which had substantial piled foundations to limit deflection. The mould was raised and lowered to suit the production and stripping. The external sideforms were hydraulically stripped to provide sufficient clearance to launch, as webs were near vertical.

At the abutment, Structural Systems' launching equipment was used to progressively launch the 50,000kN structure. A calculated thrust of 3,200kN was required for the final launching.

AWARD WINNING PROJECT

This successful and innovative project has received many awards and was recently recognised by the Concrete Institute of Australia who selected the project as the overall winner of the Kevin Cavanagh Medal. Awarded just once every two years, this medal is the premier award and is made on the basis of Excellence in Concrete – the winner is chosen from all projects nominated Australia-wide.

This project demonstrates admirably that the Alliance approach can be the right solution, given certain circumstances. To design and construct this project by more conventional mechanisms would have added perhaps 12 months and millions of dollars to the cost – as well as adding still further to community dislocation. The main construction contractor was able to provide key support and leadership in this project, which has delivered a highly challenging and spectacular structure to the Wollongong district – and indeed to Australia's road network.

Rock falls and embankment failure had been very regular over the lifespan of the road, with over 50 rock falls reported between 1996 and 2003. The road was finally closed in 2003 after major cracks up to 1m wide developed.

The incrementally launched bridge was constructed at the northern abutment and launched south over piers 1 though to 7.

Bridge TO THE FUTURE

MIDDLE BRIDGE ACROSS SUNGEI PONGGOL, SENGKANG NEW TOWN, SINGAPORE

The latest technology for monitoring the post-construction behaviour of structures is being embedded into Middle Bridge, currently under construction across the Sungei Ponggol in Singapore. **BBR Construction Systems Pte** is providing technological support and services to the project which is due for completion by April 2008.

As part of the infrastructure development works for Sengkang New Town, the Singapore Housing and Development Board (HDB) decided to construct a vehicular bridge across Sungei Punggol to serve the future development in that area. Together with their designer, Surbana International, they designed a pair of three span balanced cantilever bridges, with mid-spans of 105m and end-spans of 75m. The width of each bridge is about 17m.

Singapore Piling And Civil Engineering (SPACE) – a wholly-owned subsidiary of BBR Holdings Singapore – in collaboration with BBR Construction Systems, tendered for and was awarded this project in September 2006.

WORK SCOPE

As main contractor for the project, the scope of works includes bored piling, earthworks, reinforcement and concreting works, box culvert drains, bearings, expansion joints and, of course, all the post-tensioning works, including the design, fabrication and operation of two pairs of form travellers.

SEGMENT CONSTRUCTION

Each bridge consists of 64 segments of cast in situ balanced cantilever prestressed box girder. Segment length varies from 3m to 4m. Cycle time per segment is targeted at seven days on average, with the deeper segments at the hammerhead taking slightly more time compared to the smaller segments towards the mid-span.

FAST-TRACKING

The original intention was to construct one of the bridges first and use this newly-constructed bridge as an access for construction of the other one. However, due to the time constraints, we decided to fast-track the works programme by using the form travellers for the mid-span concurrently for the two bridges, using a conventional scaffold system for the end-span.

WATER WORKS

As the four main piers are located in the river, the method being used for their construction involves backfilling from the riverbanks to the piers. Sheet piles were driven in as temporary earth retaining structures. A second layer of sheet piling was used together with two layers of strutting, as a temporary cofferdam for the construction of the four main pile caps and piers. The excavated depth to the pile cut-off level is about 10m and the soil movement monitoring, which is a requirement for deep excavation works, was carried out throughout for each pile cap construction with geotechnical instruments, i.e. inclinometer, piezometer and water standpipe.

POST-TENSIONING

The post-tensioning tendons consist mainly of 22 15.7mm diameter strands utilising BBR CONA internal anchorage systems. Hydraulic jacks of 480t capacity are used for the stressing of these tendons.

FIBRE OPTIC MONITORING

In collaboration with a local specialist, we have designed and implemented an in situ Structural Health Monitoring System (SHM) for the Middle Bridge.

Eight types of devices are used to monitor static behaviours of bridge components and corrosion of foundations. Upon completion of construction and when the bridge is open to the traffic, dynamic measurements are required for vibration mode analysis. The same sensors are used for both static and dynamic measurements.

Fibre optic sensing (FOS), the latest technology for SHM, was used in this bridge. For concrete structures, FOS is embedded into the steel reinforcement cage at the concreting stage or, for existing structures, mounted on the surface of the concrete with coating protection. The sensors are accurate, free of calibration, not prone to signal loss over long distances and suitable for long-term usage.

TEAM & TECHNOLOGY

OWNER
Housing and Development Board

MAIN CONTRACTOR
Singapore Piling and Civil Engineering

SPECIALIST SUB-CONTRACTOR
BBR Construction Systems Pte Ltd

DESIGNER
Surbana International Pte Ltd

TECHNOLOGY
BBR CONA internal

BBR NETWORK MEMBER
BBR Construction Systems Pte. Ltd. (Singapore)

POST-TENSIONING FOR SLABS

Optimising with **BBR technology and expertise**

Designers, builders, owners and users of buildings require more efficiencies today than ever before. BBR slab post-tensioning systems offer all the stakeholders in a building project many benefits, as well as reducing environmental impacts.

→

Whether for ground slabs or suspended floors, the advantages to be gained from using post-tensioned solutions are immense. Used for decades in Australia and the United States, post-tensioned slabs are now becoming popular throughout the world, as the enhanced value they deliver is being recognised by clients, developers and construction professionals.

The post-tensioning of slabs is a highly efficient method that offers many benefits in a wide range of structures, such as residential and commercial buildings, industrial floor slabs on the ground, parking structures, water tank bases and transverse stressing of bridge decks. A post-tensioned slab is the perfect balance of concrete and steel. Concrete is strong in compression and weak in tension and steel is best used in tension.

ARCHITECTURAL FREEDOM

For the same depth, longer spans are possible with post-tensioning. In buildings, this can mean larger column-free space as spans up to 15 metres are common in standard post-tensioned slabs. Post-tensioned concrete can easily be adapted to accommodate complex geometry and special design challenges necessary to meet all the needs of modern architecture.

MATERIAL SAVINGS

Post-tensioned slabs are normally about 30% shallower and – due to the fact that prestressing steel has a very high tensile strength which is about four times that of common reinforcing steel bars – also require significantly less steel. With the rising cost of concrete and steel, this can be a major factor! The reduction of slab thickness reduces the building height and consequently the costs of all related building components. In multi-storey buildings, a reduction of the floor height often permits the addition of one or more floors – with no increase in total building height. In the case of underground structures or slabs on ground, PT can lead to reduction in the cost of excavation, soil retention systems and dewatering in areas with high water tables.

CONSTRUCTABILITY

Post-tensioning can enhance the speed of construction and overall constructability. High-rise buildings can be constructed very quickly using post-tensioned concrete and earlier stripping of formwork can significantly reduce the floor-to-floor cycle time, the need for formwork and the construction time.

SERVICEABILITY

PT structures are durable and require little maintenance because the compressive forces that are applied to the structure during prestressing result in better crack and deflection/vibration

"POST-TENSIONED STRUCTURES DESIGNED AND CONSTRUCTED WITH A LIFECYCLE APPROACH ARE ENVIRONMENTALLY SENSITIVE AND ACTUALLY SAVE MONEY FROM THE FIRST DAY ONWARDS."

Metuljcek, the "little butterfly", nears completion in the Slovenian ski resort of Kamnik – a commercial and residential development with underground parking which has benefited from a BBR CONA post-tensioned floor solution.

This distribution centre, approaching 32,000m^2, was constructed for a large superstore retailer in New Zealand. Using BBR-developed special design application software, BBR Contech was able to ensure maximum floor size and a minimum number of joints. The level of post-tensioning varies depending on the rack and vehicle loadings, but tendons are typically configured using BBR CONA flat 405 bonded cables at 1.5-2m centres.

" ..... BY ADDING EXTERNAL PT TENDONS, THE LIFE OF A STRUCTURE CAN BE EXTENDED WITH MINIMAL ENVIRONMENTAL IMPACT."

control. Monolithic connections between slabs, beams and columns can eliminate maintenance-intensive joints between elements.

ENVIRONMENTAL IMPACT

BBR VT International Ltd's CEO, Marcel Poser, states that by carefully considering the entire lifecycle of a building at the outset – from the building placement, through the design and construction, onto early considerations on re-usage and ultimate disposal – post-tensioned structures are environmentally sensitive and actually save money from the first day onwards.

The correct use of post-tensioning helps lower the environmental impact of a building by reducing the quantities of steel and concrete used – whilst, at the same time, it increases construction speed and reduces the need for construction gear and items such as formwork. The cement manufacturing process is one of the largest producers of greenhouse gases and, by increasing the slenderness of the structures using PT, less concrete, less cement and therefore less CO2 is emitted. The reduced floor-to-floor height results in a smaller building envelope that saves exterior finishing material and reduces energy usage for heating, ventilation and air conditioning. In parking structures, the openness of post-tensioned designs allows for improved lighting and more efficient energy usage and safety. Structures can be easily adapted for re-use through post-tensioning – by adding external tendons, the life of a structure can be extended with minimal environmental impact.

WORLD CLASS BBR KNOW-HOW

Structural detailing and sound construction practices are an art that develops with experience and sound understanding of post-tensioned structures – but it is the essential part of a cost-effective and reliable structure. The BBR Network can offer design and construction input from initial advice to fully detailed design for construction drawings to ensure that the design and floor configuration meets the specified performance requirements. The Network has worked closely over many years with builders and construction personnel resulting in a well understood system which enhances the construction process. BBR offers two specific post-tensioning systems for slab post-tensioning. The unbonded CONA CMM post-tensioning system, consisting of 1, 2 or 4 seven-wire prestressing mono-strands, where each strand is manufactured with a flexible corrosion inhibitor and an individual HDPE sheathing, and the bonded CONA CMF post-tensioning system with 1 to 6 strands inside a post-grouted flat steel or flat plastic duct.

Benefits of post-tensioned slabs

- Reduced structure depth
- Larger clear spans
- Design flexibility
- Formwork versatility
- Reduced construction costs
- Enhanced construction speed
- Improved durability
- Reduced environmental impact
- Minimised maintenance costs

SUBIC BAY PORT DEVELOPMENT, LUZON ISLAND, PHILIPPINES

When Subic Naval Base – the largest American Naval Base outside of the United States of America – was closed in 1991, it was converted into a Free Port. With its natural deep water harbour, international airport and skilled work force, the Subic Bay Freeport Zone has become a major economic hub.

To maximise the economic potential of the Subic Bay Freeport Zone and the Clark International Airport Zone – a

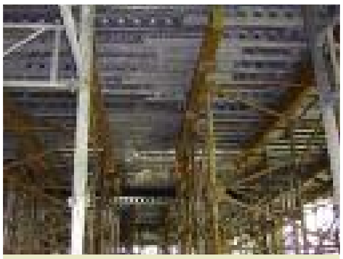
PT CONDOMINIUM TRANSFER FLOOR, KUALA LUMPUR, MALAYSIA

Alternative advantages

All beam tendons installed before first stage casting

Slab tendons and wall starter bars installed before second stage casting

Stage 1 tendons stressed and forces in props released before Stage 2 casting



Heavy duty scaffolds to support half of total concrete weight

BBR MALAYSIA **proposed an alternative design for this project which now uses BBR post-tensioning as construction formwork and as part of the permanent structure – saving costs and creating more space.**

The 12-storey condominium tower comprises reinforced concrete walls supporting reinforced concrete slabs at each floor. The loads from the walls are transferred at seventh floor level to the car park structure below. The car parking floors were post-tensioned with grouted tendons.

THE CHALLENGE

The original transfer floor consisted of 1.5m deep reinforced concrete beams. As well as the disadvantage of reduced headroom below, it would have been costly to provide falsework to support the concrete loads. A third problem was the heavy construction loads that needed to be carried by many floors below as they were only designed for car park loading of 3.0kN/m^2 imposed load – which is relatively light.

ALTERNATIVE DESIGN

BBR Malaysia proposed an alternative design using post-tensioned beams and slabs. Live loads from the reinforced concrete walls sat on the slabs or beams. Maximum depth was 1m for beams and 0.5m for slabs. Post-tensioned flat plates were not possible due to the irregular layout of columns and long cantilevers. The post-tensioning technology used was BBR CONA internal 705 tendons for the beams and BBR CONA flat 5x5 tendons for the slabs.

PT OPERATIONS

The solution was provided by casting the concrete in two stages with partial post-tensioning for the first stage. For the first stage, concrete was poured up to 0.6m of the beam depth. When concrete strength reached 30N/mm^2, the first group of tendons embedded within the 0.6m concrete were stressed. Next, the screw jacks of the heavy duty scaffolds were loosened. At this point, the weight of the first cast was carried by the tendons back to the columns – the structure was then self-supporting. Next, the screw jacks were retightened to receive the impending loads from the second cast. Thus, the scaffolds supported about half of the total concrete floor load at each stage of the casting. Consequently, only one level of backpropping was necessary for the sixth floor. After stressing of the second stage tendons, all falsework was removed and construction of reinforced walls began.

TOP SCORE

The moments, stresses and deflection of the two stage casting were analysed using a prestressed finite element programme. We also checked the long term stresses in the structure to carry the service loads of the tower. By combining powerful modern computer analysis techniques, along with the strong and trusted BBR tendons, we solved the problem of dealing with the massive concrete loads on scaffolds and floors below – and, at the same time, gave the client the added benefit of improved headroom.

Gateway to new economic zone

former American Air Base which was devastated by the eruption of Mount Pinatubo in 1990, the Philippine Government is building the Subic-Clark-Tarlac Expressway Project to link vital economic nodes in the central part of Luzon Island.

DEVELOPMENT PROJECT

As shipments for the Clark International Airport Zone enter the Philippines through the Subic Bay Freeport Zone, it became clear that the old port facilities would be inadequate for the increasing volume of commercial traffic. To remedy the situation, the Philippine Government decided to undertake the Subic Bay Port Development Project.

PT SLABS

Part of the project involved the fabrication of 1416mm to 350mm thick pre-cast, pre-tensioned slabs and the construction of 512 250mm thick cast in situ post-tensioned slabs. They form part of the container stacking foundations in the new container terminals. The total area of the slabs is approximately 47,000m^2 and the total volume of concrete is approximately 14,000m^3. **BBR Philippines Corporation** utilised BBR CONA flat 205 and 405 tendons for the post-tensioned slabs. The total weight of prestressing steel for the project is more than 500t.

The pre-tensioned slabs have widths ranging from 1m to 2m and lengths ranging from 6.29m to 9.10m. The post-tensioned slabs have widths ranging from 1.5m to 2m and lengths ranging from 10.5m to 40.8m.

With the successful completion of the Subic Bay Port Development Project, another vital piece of infrastructure has been put in place that will help propel the Philippines' drive towards greater economic success.

Mabuhay!

CHANGI DISTRICENTRE, SINGAPORE

LOGISTICAL GOAL

C&P Changi Districentre is a massive six-storey building – the tallest warehouse in Changi South Road, located in the eastern part of Singapore. **BBR Construction Systems Pte Ltd** reports that it was completed and successfully handed over to the client early in 2007.

The client was C&P Holding Group – the largest logistics, transportation and warehousing development company in Singapore. The anchor tenant is an established US logistics company, TNT, who uses this warehouse as a transshipment hub for life sciences materials and medicine to the Asia-Pacific Region.

TEAM & PROJECT

BBR Construction Systems Pte Ltd was engaged by JH Builders Pte Ltd to design, supply and install the post-tensioning systems in all the horizontal elements for the entire warehouse. The 50,000m^2 warehouse scheme consisted of four zones – warehouse, driveway, ramp and ancillary office – and there was a 12 month programme for the whole of the construction project.

HEIGHT RESTRICTIONS

The close proximity of the project site to Changi Airport meant that the building would be subject to a maximum height restriction. The major challenge during the design stage was to reduce beam depths and slab thicknesses, so that the overall building height would not exceed the height limits set by the Urban Re-Development Authority – and, at the same time, ensure that the required headroom usage would not be compromised.

The adoption of post-tensioning for this project not only achieved the client's objectives, but the PT solution also meant that the resultant smaller structural member size and thinner slabs reduced both foundation load and overall building cost.

TEAM & TECHNOLOGY

CLIENT
C&P Holding Group

CONTRACTOR
JH Builders Pte Ltd

TECHNOLOGY
BBR CONA internal
BBR CONA flat

BBR NETWORK MEMBER
BBR Construction Systems Pte Ltd (Singapore)

Complex and challenging project

THE LINKS SEASIDE, WOLLONGONG, NSW, AUSTRALIA

The Links Seaside, is a new residential development located in Southern New South Wales on Wollongong Golf Course and overlooking City Beach. The Links Seaside will offer residents spacious, luxurious surroundings combined with a wide array of services and first class recreational facilities. Sam Fassaie of BBR Network member **Structural Systems Limited (Australia)** gives an overview of the project.

Structural Systems was awarded the design and construction for the post-tensioning of the project by Wideform Constructions. This included the basement raft slab (12,850 m^2), ground floor podium (12,560 m^2) and Building C – Level 1 (3,560 m^2).

SOIL CHALLENGES

As the site soil conditions were not quite suitable for such a large scale development, detailed design co-ordination was required between Structural Systems and the geotechnical and head consulting engineers. To avoid excavation in the existing loose ground, it was decided that the optimum solution would be a 400mm to 550mm thick post-tensioned raft slab. The magnitude of the transfer loads dictated that Structural Systems' design team should select strands with higher tensile strength in order to avoid tendon congestion.

DESIGN SHEAR

There were serious punching shear problems in the basement slab which did not allow the conventional use of closed ties or stud-rails. Instead, shearheads made of steel profiles were devised to resist the punching shear forces. This, however, made the design, detailing and, in particular, the installation of post-tensioning tendons on site very complicated. In order to accommodate shearheads, two layers of mesh (top and bottom), top and bottom reinforcement in 400mm and 550mm thick slabs, and the post-tensioning tendons running both directions required days of discussion, planning and co-ordination. Thanks to the expertise of those involved on the project, there were minimal problems on site during construction.

COMPLEX PODIUM

The ground floor (podium) slab posed very complex concrete profiles due to the combination of down-turn and up-turn beams, rebates, folds, steps, varying slab thicknesses, diagonal beams – and the multitude of transfer columns on the slab. Similar to the basement slab, strands with higher tensile strength were used.

The slab thicknesses and the beam sizes were reviewed by the Structural Systems' design team to create the optimum design for the ground flood slab. This had to be carried out in co-ordination with the head consulting engineers, architect and the services consultants.

These revisions led to significant changes in the concrete outlines which were approved by all relevant parties. The podium level consists of 14 pours which have been separated by construction joints and expansion joints.

EXPANSION JOINTS

Though corbels are generally the most common option for expansion joints, because of architectural considerations, corbels could not be designed for all expansion joints in this slab. Therefore, the application of shear connectors with high shear capacity in some expansion joints was essential, given free horizontal movement in both directions had to be achieved.

Building C, Level 1 consisted of seven pours which were designed and constructed simultaneously with the ground floor slab. Similarly, shear connectors were applied in the expansion joints in this level. The construction of Level 1 slabs was completed in June 2007.

TEAM & TECHNOLOGY

OWNER
Wideform Constructions

CONTRACTOR
Wideform Constructions

DESIGNER
Structural Systems Limited (Australia)

TECHNOLOGY
BBR CONA flat

BBR NETWORK MEMBER
Structural Systems Limited (Australia)

Embracing PT floors

Bridgewater Place in Leeds, pictured here, is one of three major residential schemes undertaken in recent months as the UK construction market starts to embrace the advantages of post-tensioned floors. On the following pages, the team from BBR Network member **Structural Systems (UK) Ltd** takes up the story. →

BRIDGEWATER PLACE, LEEDS, UK

Graceful & **awe-inspiring**

Bridgewater Place is a graceful yet awe-inspiring 32-storey tower development in the business quarter of Leeds, one of the UK's principal northern cities, reports Kevin Bennett, Technical Manager of **Structural Systems (UK) Ltd.** Located just minutes from the rail and motorway connections, it has already attracted a major firm of solicitors as main tenants.

The nine lower storeys house 23,000m^2 of high quality office space in two buildings separated by the largest feature atrium in Leeds – 1,500m^2 of retail and leisure facilities are also contained in these lower levels. Rising majestically and offering superb panoramic views, the residential tower provides 200 luxury apartments within its additional 23 levels. The basement offers 400 car parking spaces. It is estimated that Bridgewater Place will accommodate 3,000 people per day in its iconic 110m tall structure.

MAXIMISED FLOOR SPACE

Consulting engineer Mott Macdonald selected post-tensioning for the slabs in order to maximise the floor space available within the building envelope – the thinner slabs allowing more storeys to be accommodated in a given height. A second significant benefit was the vast reduction in steel content that post-tensioning brings, with the project being started when world steel prices were very volatile. The reduction in financial risk by selecting post-tensioning was a factor in deciding to proceed with the project.

Technical details

Typical loading for the offices is 4.0kN/m^2 (live) and 1.5kN/m^2 (dead superimposed) and this requires 225mm thick PT slabs to span the 9m by 7.5m grid, a span-to-depth ratio of 40. Plant loading (7.5 plus 2kN/m^2) necessitated slab depths of 270mm on levels 9 and 10. Tendon spacings vary between 800-1000mm for column strips and 1500-1700mm for middle strips, leading to a P/A of 1.7MPa in the longer span direction and 1.5MPa the other way.

The residential floors are 17m wide and range in length between 46m and 40m. Slab depth stayed at 225mm for the residential loading (1.5 plus 1.5kN/m^2) in order to control deflections for the cladding.

RESTRAINT SOLUTION

The office levels comprise two floor plates which measure 120m by 17m and 76m by 17m. Both blocks contain two reinforced concrete cores and, in order to solve the restraint issue, Structural Systems introduced a temporary movement joint across both floor plates. This comprised sleeved dowels crossing the construction joint between two pours. Once sufficient slab shortening had occurred – 28 days after stressing the second pour – the sleeves were grouted to lock the joint and restore structural integrity to the floor plates.

FAST BUILD

It was important to construct the building quickly and the reduced quantities used in PT construction helped P.C. Harrington (Contractors) Limited, the concrete frame contractor, achieve floor-to-floor cycles of just three days.

The project is now completed and the majority is let ... but, if you're really quick, you may just be lucky enough to catch one of the panoramic penthouses on the 32nd floor!

TEAM & TECHNOLOGY

OWNER
St James Securities/Landmark Development Projects

CONTRACTOR
Bovis Lend Lease

DESIGNER
Connell Mott MacDonald

TECHNOLOGY
BBR CONA flat

BBR NETWORK MEMBER
Structural Systems (UK) Ltd

QUEEN STREET, PORTSMOUTH, UK

NEW WAVE elegance

Sleek, stylish and with award-winning architecture, the vision for Queen Street is to make a positive contribution to the skyline of Portsmouth. At the same time, the scheme is focused on providing unsurpassed value-for-money homes which complement the surrounding area and are sympathetic to historic landmarks, whilst being central to the regeneration of the city and harbour. Kevin Bennett, Technical Manager and Alina Wiaz, Project Design Engineer – both from STRUCTURAL SYSTEMS UK LTD – tell how this major project is shaping up.

The Queen Street scheme is part of a new wave of very large projects currently being constructed by Ardmore Construction. This superb development, being constructed in two phases, is Ardmore's first using post-tensioning. They were persuaded to go with PT by structural engineers Cameron Taylor who had used it on the earlier Montrose Place project in London – another Structural Systems UK job.

PROJECT DETAILS

The project comprises the construction of 569 apartments in 17 buildings up to seven storeys high – arranged around the perimeter of the site – plus a landmark tower 22 storeys high. A two level car park covers most of the site area with upper floor private gardens within the centre of the development. Retail units occupy the ground floor of some of the buildings.

The two storey car park is formed from 225mm thick post-tensioned concrete slabs with an entrance at ground level. The roof of the car park, in the centre of the development, is used to support landscaped gardens and these PT slabs are 350mm thick.

CLASSIC ATTRIBUTES

Post-tensioning was introduced to this project because of two of its classic attributes – thin slabs for long spans, plus very little conventional reinforcement. This permits fast construction times. The site is in the centre of Portsmouth and the reduced quantities of concrete and steel in a PT job also have a direct benefit on traffic volumes in such city centre locations.

The post-tensioning system adopted is the BBR CONA flat 505 bonded tendon system, Comprising up to five 12.9mm diameter high yield strands inside a flat galvanized steel duct. After stressing, the ducts are injected with cement grout to provide bond and corrosion protection.

MEETING CRITERIA

The uplift forces generated from the parabolic tendon profiles balance much of the dead loadings. This means long-term creep deflections are virtually eliminated allowing the stringent deflection criteria of the curtain walling to be achieved without edge beams. Eliminating edge beams is important to allow the table forms to be used at their optimum efficiency.

The post-tensioned flat slab thicknesses are typically 225mm for a 7.5m by 7.8m grid. Occasional spans of up to 10.2m are handled by locally thickening the slabs to 275mm. The strength of concrete used in the design of post-tensioned floor slabs is 40 N/mm^2.

The vast 200m by 100m development is divided into 17 separate buildings by movement joints. Shear connectors are being used to transfer shear across many of these movement joints, back to supports.

"POST-TENSIONING WAS INTRODUCED TO THIS PROJECT BECAUSE OF TWO OF ITS CLASSIC ATTRIBUTES – THIN SLABS FOR LONG SPANS, PLUS VERY LITTLE CONVENTIONAL REINFORCEMENT."

Structural Systems UK's in house design team in Southall has designed all of the post-tensioned slabs and, as the project nears completion on site, the tall ships in the adjacent historic dockyard will soon be complemented by this elegant and modern addition to the Portsmouth Skyline.

TEAM & TECHNOLOGY

OWNER
Crest Nicholson

CONTRACTOR
Ardmore Construction Ltd

ARCHITECT
David Richmond & Partners

DESIGNER
Cameron Taylor

TECHNOLOGY
BBR CONA flat

BBR NETWORK MEMBER
Structural Systems (UK) Ltd

HAYES CENTRAL, MIDDLESEX, UK

OPTIMISED for speed

Stuart Crole, General Manager of **Structural Systems (UK) Ltd** reveals the story of how a different type of steel has started to sprout from the ground of the old scrap yard at Hayes, in Middlesex.

As an up-and-coming area, the site represented prime development land – and, being located adjacent to the Grand Union Canal and Hayes and Harlington Station, the location provides easy access into London.

SCHEME OVERVIEW

The 72,100m^2 Hayes Central scheme comprises seven blocks of mainly residential units – with one block providing a hotel on the complex. The majority of the blocks spring nine floors from a podium deck at level 1, with one rising to ten floors. The mezzanine level provides parking for the residents and the hotel.

PT DESIGN

The initial scheme was designed by Walsh Associates as a post-tensioned solution, typically utilising an 8.35m by 6m column grid. The final post-tensioned slab design is being constructed by a combination of SSL in the UK and SDS in Poland. The slab depths vary depending upon loadings and include a 210mm slab, 225mm for the internal podium and the residential/hotel slabs, and a 300mm for the podium slab where this is externally located.

The average pour size of the scheme is 520m^2 – with around 13 pours per floor for the residential areas, 12 pours for the mezzanine and 18 pours for level 1. The scheme features some 72,100m^2 of post-tensioning.

FAST & SIMPLE

Discussions with the frame contractor, P.C. Harrington (Contractors) Limited, resulted in minor changes to provide a faster and simpler construction process, which delivered programme benefits.

Post-tensioning, which uses the BBR CONA flat fully bonded system, is due to be completed in July 2008.

TEAM & TECHNOLOGY

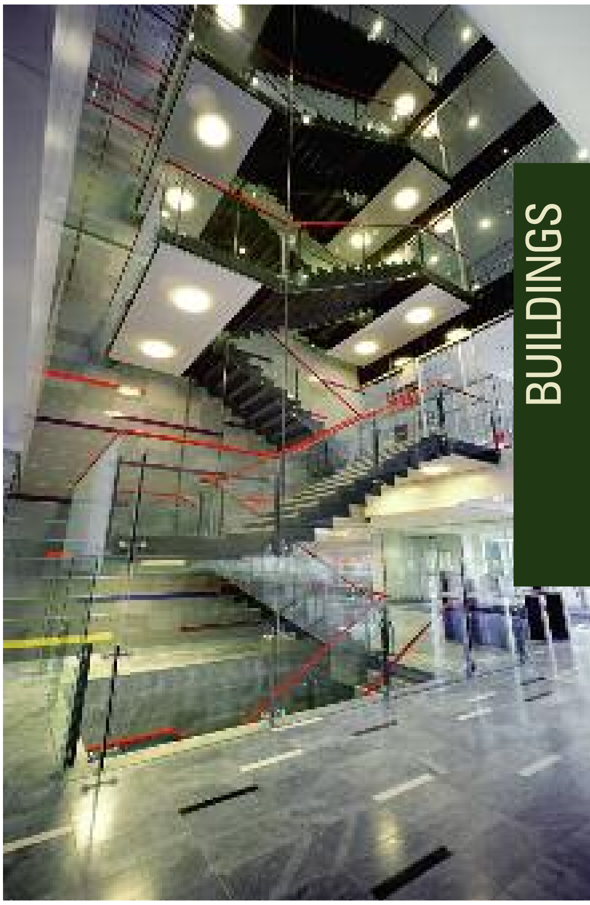
OWNER
Ballymore Properties

CONTRACTOR
Ballymore Properties (main)
P.C. Harrington Contractors Ltd (frame)

DESIGNER
Walsh Associates (Structural Engineer)
Structural Systems (UK) Ltd & SDS (Poland) (slab design)

TECHNOLOGY
BBR CONA flat

BBR NETWORK MEMBER
Structural Systems (UK) Ltd



Stringent deflection requirements from the clients were achieved for all slabs and bands, the inter-floor differential deflection was especially strictly controlled to suit the high standard of glass and stone façade.
Great and timely efforts were made by Structural Systems to ensure all special details – such as security, fire, temporary and permanent joints etc – were well-incorporated by the post-tensioned floor systems, ultimately ensuring that the building was finished to the highest possible quality.

THE PRIME MINISTER'S OFFICE, CANBERRA, AUSTRALIA

Great and timely efforts

Construction of the offices, at 1 National Circuit in Canberra, for the Prime Minister of Australia and his Cabinets has been completed. Carl Xu of **Structural Systems,** the BBR Network member in Australia, explains the challenges of this prestigious project.

The building consisted of five levels of offices and two car park basement levels – with a total of 28,300m^2 of post-tensioned slabs.
In view of the regular column grids and large span arrangement design, a one way post-tensioned banded slab floor system was suggested by Structural Systems and approved by the builder Bovis Lend Lease. The one way banded floor systems not only provided economic and structural benefits, but also ensured construction speed and high quality of construction work. The bonded BBR CONA flat anchorage post-tensioning system was used throughout the project. Around 200t of PT strands were used in the project.

TEAM & TECHNOLOGY

OWNER
Industry Superannuation Property Trust

CONTRACTOR
Bovis Lend Lease

DESIGNER
Peckvonhartel

TECHNOLOGY
BBR CONA flat

BBR NETWORK MEMBER
Structural Systems Limited (Australia)

Modern marvel

LAKE TERRACE, DUBAI, UAE

The post-tensioning works on the 44-storey high-rise tower of the Lake Terrace project in Dubai has been completed, reports Warwick Ironmonger of NASA Structural Systems LLC. Situated in the 730,000m² Jumeirah Lakes district of Dubai, the high-rise tower will overlook the 116,000m² man-made lake and the project will be surrounded by extensive lawns and recreational parks.

OPTIMUM SOLUTION WITH PT

Lake Terrace is a marvel of contemporary architecture. Due to the unusually long spans, post-tensioning was the optimum solution. In addition, it provided a manageable and economical structure facilitating a reduction in floor-to-floor construction cycle times.

NASA Structural Systems LLC was contracted to undertake the design, supply and installation of 205t of post-tensioning – covering a total area of approximately 46,500m².

TECHNICAL REQUIREMENTS

The typical residential levels consisted of 500mm deep by 1800mm wide post-tensioned band beams, spanning 13m between supporting shear walls, whilst supporting the 180mm post-tensioned slabs. However, plant floor requirements necessitated the implementation of a 400mm thick – essentially one-way – post-tensioned flat slab, spanning the 13m between the supporting shear walls.
The 206 and 506 slab anchorage systems were combined effectively to permit significant spacing of the slab tendons, whilst maintaining sufficient concentration of the tendons within the beams.

TEAM & TECHNOLOGY

OWNER
DAMAC Properties

CONTRACTOR
Al Hamed Development & Construction Co.
China State Engineering & Construction Co.

DESIGNER
WS Atkins & Partners Overseas

TECHNOLOGY
BBR CONA flat

BBR NETWORK MEMBER
NASA Structural Systems LLC
(United Arab Emirates)

FLOORING successes

Over the past few years, **BBR Contech** has worked with a number of New Zealand's best known businesses to design and install post-tensioned floors. These high-performing systems are ideally suited to large commercial and industrial environments, offering a total absence of joints – the single largest contributor to failures in traditional floors – a smooth appearance, high resistance to applied loading, easy care and long-term durability. ➔

MEGAFLOORS FOR MEGASTORES

BBR Contech's association with DIY giant Mitre 10 continues with three new projects in Upper Hutt, New Plymouth and Ferrymead – bringing the tally to 12 stores nationwide. The floors are ideally suited to the company's megastores, offering a smooth surface for retailing, storing and moving goods and materials. Averaging 6,500m^2 in area – and requiring pours of 500-600m^3 of concrete – other post-tensioned floors can be found in megastores in Hastings, Napier, Petone, Wanganui, Nelson, Hornby, Dunedin and East Tamaki and Papakura.

The latest three stores are being built by Armstrong Downes (Upper Hutt) and Calder Stewart (New Plymouth and Ferrymead).

BBR Contech has designed and installed post-tensioned building solutions for all types of businesses, including those in the logistics, distribution and retail sectors – they all share market-leading reputations – and a need for high quality floors.

PREMIUM SOLUTIONS

The direct motorway access to Highbrook is now operational, giving direct and fast access to this world class business park comprising some 150 hectares of premium commercial property. Located alongside water and green open spaces – and just 15 minutes from the Auckland Central Business District (CBD) and airport, Highbrook has attracted some of New Zealand's leading companies such as DHL, NZ Post and BMW.

The award-winning layout has been developed by Goodman Ltd – one of Australasia's premier developers. The site has a commercial land area of 107 hectares with an additional 40 hectares of public park space, esplanades, sports fields and 14km of walkways.

With a strong commitment to quality and innovation, Goodman has selected post-tensioned floors for many of the Highbrook development sites. DHL was one of the founding tenants and its first warehouse boasted a 14,000m^2 post-tensioned floor. DHL is proudly located at the entrance of the business park and is a prime example of the quality of tenant that clients can expect in this development.

"YOU (AND THE BBR CONTECH TEAM) WERE, AS ALWAYS, ABLE TO DO BETTER THAN PRO-GRAMME WITH A MIND-SET AND KNOWLEDGE BASE TO MATCH."

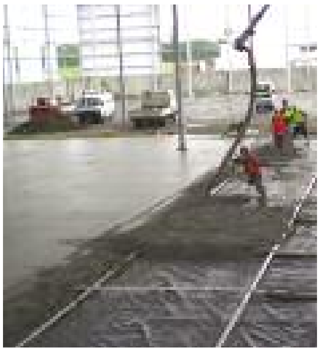
The facility has been rapidly expanded and two warehouse extensions have been added in recent times, bringing the total post-tensioned floor area to some 30,000m^2.

These impressive modern commercial facilities were designed by MSC Consulting and constructed by Haydn & Rollett. The floors were installed by full delivery contractor Conslab, with BBR Contech providing the post-tensioning services.

GROCERY PACKAGE

Foodstuffs' is New Zealand's largest grocery distributor and its newest warehouse, completed early in 2007, is located in Hornby, Christchurch.

Working as a subcontractor to full delivery floor specialist, Conslab, BBR Contech's job was to install post-tensioning for a 10,700m^2 floor slab designed by consultant Evans Douglas. The 180mm slab was poured in three stages and used five-strand tendons as well as conventional reinforced steel.



The main building contractor, Armitage Williams Construction was very pleased with the performance of the flooring team and praised those involved in the project.

"Further to completion of the above project, we write to express our appreciation for the way in which Conslab carried out their subcontract for this project. The client set a challenge to our company to deliver completion in a very short time frame. We achieved the completion date with the help and commitment of Conslab. The quality of the finish achieved was excellent and we have received compliments from our client for the high standards of workmanship delivered. We are proud of the result achieved on this project as you should be, and we look forward to working with your company on future projects. Please pass on our appreciation to all your staff involved."

Paul Blackle, General Manager Construction
& Mark Blyth, Director
Armitage Williams Construction

BBR Contech has worked in close partnership with Conslab on a large number of post-tensioned slabs throughout New Zealand and is pleased to be associated with another successful project.

Following on from this, another Foodstuffs' project is currently under construction and the latest building is a very large scale distribution centre. With a total floor area in the vicinity of 40,000m^2, this will be one of the largest post-tensioned slabs on grade installed in New Zealand to date. Completion is scheduled for 2008.

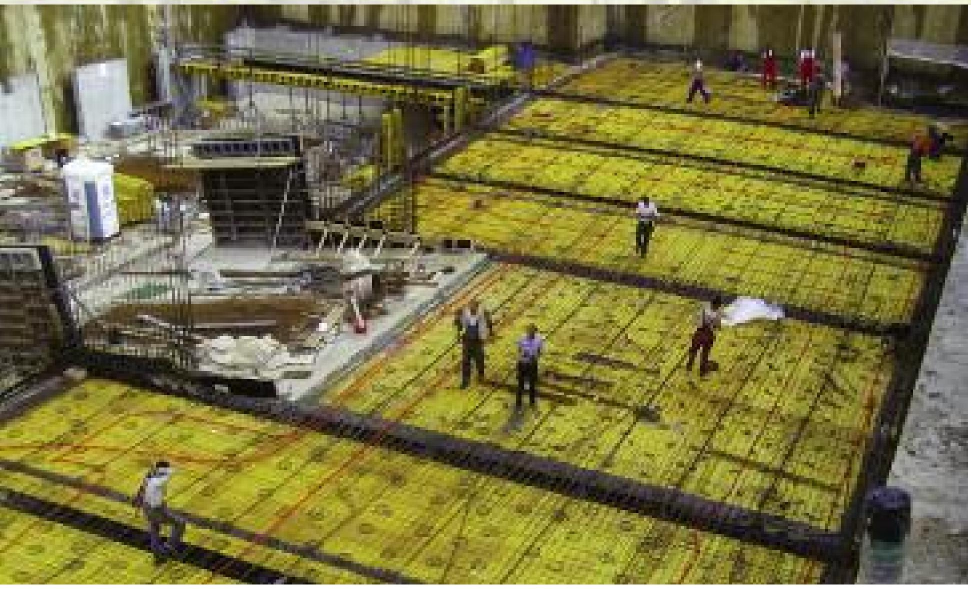
SMOOTH SHOPPING

Auckland's latest shopping destination, the magnificent Sylvia Park, is proving a huge attraction for shoppers throughout the city – and BBR Contech is delighted to have made the "trolley experience" a little smoother for many, with a post-tensioned floor in the new flagship store, The Warehouse Extra.

The 10,000m^2 joint-free expanse offers not only great aesthetics and minimal requirements for maintenance but also a reinforcement of The Warehouse brand – a result BBR Contech has already achieved in a number of other projects with The Warehouse and construction company Naylor Love. A smooth, durable and joint-free surface is just what is required to cope with the many customers visiting the store each day.

Soon after completion, BBR Contech's Northern Regional Manager, Keith Snow was delighted to receive a letter from Steve Walker, Naylor Love's Contracts Manager: "Keith, a big thank you for Contech's involvement in The Warehouse Sylvia Park. You (and the BBR Contech team) were, as always, able to do better than programme with a mindset and knowledge base to match. A pleasure to deal with you and a successful outcome. A job well done."

Winning hearts and minds



TEAM & TECHNOLOGY

DEVELOPER
Zagrebparking, Croatia

CONTRACTOR
Tehnika, Zagreb

DESIGNER
APZ-inzenjering, with Dreibau Ingenieurs Conseils (Switzerland)

TECHNOLOGY
BBR CONA unbonded

BBR NETWORK MEMBER
BBR CONEX (Croatia)

TUSKANAC PARKING GARAGE, ZAGREB, CROATIA

The Tuskanac parking garage in Zagreb provides parking for 475 vehicles on five levels and incorporates a green roof with a promenade, pedestrian walkways and a basketball pitch. It includes all parking, auxiliary areas, plant installations and a car wash. Damir Paviãiç of **BBR CONEX** describes his company's fifth project with unbonded post-tensioned slabs.

The 18.5m high structure consists of a basement mat, four floor slabs and a roof slab – with a 35m by 78m footprint. Enclosed areas account for 13,330m^2 and there is a further 2900m^2 of roof and ramps. Structural features include sloped slabs with circular traffic access to the various levels – this is a patented car parking solution by Hill Cannon of London.

The Tuskanac structure started to grow in April 2007 and was completed in the autumn – a six month programme involving some 7,500m^3 of concrete and 800t of reinforcement, together with a reinforced concrete basement mat.

FITTING DESIGN

Slab design was carried out in conjunction with Swiss-based Dreibau Ingenieurs Conseils. Five floor slabs were post-tensioned, each approximately 2,500m^2 in ground plan – and which consumed 40t of BBR CONA unbonded tendons. Design and construction challenges included narrow streets, restricted site access, a high water table, minimum total building height – to fit in with the nearby historic part of Zagreb – low maintenance and moderate final cost of the structure. The original design included a 70 to 100cm deep one-directional ribbed slab with V-shaped ribs at 120 cm. Just think of all the formwork that would have been engaged for three whole weeks at a time – enough time to complete five or six formwork cycles with BBR's PT solution!

MULTIFUNCTIONAL SOLUTIONS

BBR CONEX and Dreibau offered a cast in situ solution with a one-way 14cm slab – giving a 60cm deep slab and beam section – 40cm or 50cm wide beams spanning 16m and spaced at 4.8m. The beams are thicker over the supports allowing the system to provide increased shear capacity which is needed to produce flexibility of use. The complicated car park design meant that the majority of the beams would cover just one 16m span. Beams were stressed from the top stressing pocket, as there was no room for side stressing. Deflections of the structure were minimised by pre-cambering the formwork for 80mm in the midspan of the beams – which, at the same time, solved the drainage problem!

PT SAVINGS

Post-tensioning was, once again, chosen for its structural and economical benefits. After the initial adjustments, in terms of execution and technology, the contractor started "stacking" the slabs in three weeks each, along with adjacent structures – walls, columns, stairs and ramps. Post-tensioning also permitted increased floor-to-floor heights and delivered savings in building weight. In addition, the 1.0MPa precompression in the garage slabs helps to control cracking and creates a more durable driving surface.

Much effort was spent on detailing for the release of the slab edges and beam ends, in order to minimise deflection – from the rigid walls and massive basement mat – on the slender slabs. Each slab had a pour strip on one side, to allow simpler side stressing and to allow releasing. Pour strips were left open for 14 days.

NEW ERA DAWNS

Just as on our earlier projects, the slabs were put to the test. They were tested twice with water and, once the tendon stressing had been applied, they were monitored in detail. The slabs behaved in a fully elastic manner, with deformations being fully returnable in two to three days.

Over the last few years at BBR CONEX, we had been wondering how many projects we would have to do for the scepticism about post-tensioning to fade away. However, by the end of this project, public and professional opinion in Croatia started to change and it can be said – without any modesty – that 2008 will see BBR CONEX as the prime mover in changing the face of modern civil engineering within the former Yugoslavian territories!

WOOLWORTHS REGIONAL DISTRIBUTION CENTRES

Impressive solution

Woolworths is Australia's largest grocery retailer. As part of its expansion program, reports Ian Gibbon of BBR Network member **Structural Systems,** Woolworths embarked on a plan to establish Regional Distribution Centres throughout Australia to streamline their logistics operations.

The Regional Distribution Centres are large storage warehouses surrounded by external heavy duty truck pavements. The warehouses have sophisticated pallet racking systems, enabling the fast turnaround of goods to Woolworths' retail stores.

ECONOMIC ALTERNATIVE

Both the internal warehouse slabs and the external truck pavements were originally designed as reinforced slabs over engineered subgrade. Structural Systems offered an alternative post-tensioned design for these slabs using the BBR CONA flat system. Our post-tensioned slabs were thinner with less joints and with a reduced volume of engineered subgrade. Our alternative design resulted in significant cost savings for the client.

LONG TERM SAVINGS

Woolworths acknowledged that the major reduction in the number of joints in the slabs would also save them money on future joint maintenance. Woolworths spend over $3.00 per square metre per annum on joint maintenance for conventionally reinforced slabs. Our post-tensioned slabs typically reduce the number of joints in these slabs by around 90%. This leads to significant future maintenance savings for the client.

Structural Systems designed the internal warehouse slabs as 160mm thick. These slabs were designed for racking post loads of up to 6.6t plus 6t axle loads from pallet forklifts. The external pavements were designed as 150mm thick post-tensioned slabs, allowing for standard T44 Truck Loading. Joints in these slabs were typically spaced at 50m centres.

REPEAT BUSINESS

Our first Woolworths project was at Warnervale, New South Wales. The client was suitably impressed with our post-tensioned solution and chose to use the Structural Systems post-tensioned solution on their next two distribution centres at Woodonga in Victoria and Minchinbury in New South Wales.

Structural Systems has designed over 140,000m^2 of slab on ground for these three projects. Woolworths were pleased with the substantial cost savings and the performance of the slabs and recently decided to construct their most recent distribution centre at Laverton in Victoria with our post-tensioned solution. This is another 42,000m^2 of warehouse slab on ground.

CREATING a new town

ROUSE HILL PROJECT

Chris Harris of BBR Network member, STRUCTURAL SYSTEMS, describes his company's work on Stage 1 of the Rouse Hill Project, located northwest of Sydney, Australia.

Almost 1,000t of BBR CONA flat bonded post-tensioning was shop drawn, procured, supplied, installed, stressed and grouted by Structural Systems within seven months. Used exclusively on this major project, bonded, slab system post-tensioned cast-in-situ concrete is by far the most common method of construction of suspended shopping centre floors in Australia.

The concrete outlines are mostly continuous, one-way spanning slab and band beam structures. The entire post-tensioning scope was entrusted to Structural Systems under the Strategic Procurement Alliance between Bovis Lend Lease and Structural Systems.

The site of the Rouse Hill Regional Centre consists of approximately 100ha of greenfield land and involves the development of a new planned community, including approximately 1,500 homes which revolve around a Town Centre.

The Rouse Hill Town Centre will evolve over a number of stages. Stage 2 will include a residential and commercial sleeve around the perimeter of the Town Centre, to serve as a screen and add to the level of diversity.

Facts & Figures

- 65,000m^3 of concrete
- 1,000t BBR CONA flat
- 5,300t conventional reinforcement
- 270,000m^3 earthmoving
- 1,700 reinforced cast-in-situ concrete piles.



Key role FOR GROUT

Since the introduction of post-tensioning technology in the construction market about 60 years ago, its evolution has been continuous in terms of performance and durability. In this context, it must be acknowledged that the efforts over so many years have heralded major improvements in the materials, products, specifications and working procedures.

Local standards and regulations were being adapted, at the same time as the technological advances were being made in post-tensioning systems. There is absolutely no question about the economic and technical efficiency of post-tensioning technology – and this is the reason that the time, cost and energy which have been poured into developing the technology further are totally justified. A further advantage of technological development has been the ability to deal with issues surrounding durability concerns in particular.

HOLISTIC CONSIDERATIONS

In the early projects carried out using PT technology, durability was not a concern – in the sense that it was considered an intrinsic feature of the technology itself – just as with reinforced concrete.
Practical experience in the last few decades has demonstrated this belief to have been ill-founded and has forced a more holistic consideration of durability – as a problem relating not only to the PT system in isolation, but also to the concrete structure as a whole.

MULTILAYER PROTECTION

With the introduction of the multilayer protection strategy, protection against corrosion is provided by waterproofing, dense impermeable concrete, sealed ducts and good quality grouts. The erstwhile design principles have been refocused to improve durability – and items such as waterproofing, drainage, concrete cover and concrete quality are taking a higher profile.
In the case of PT, this has been provided with a first protective barrier against corrosion – namely, grout. The second protective barrier is provided by the duct. Commonly used metal corrugated or smooth ducts do not necessary constitute permanent corrosion protection. So, to mitigate the risks, the sealing of the ducts – and the entire tendon – has been improved, and the use of plastic ducts has been introduced.

KEY ELEMENT

When looking at corrosion protection for bonded tendons as a whole, grout is a key element. This is the last protection layer in the fight to prevent corrosion and to improve durability. For unbonded systems, soft filling materials such as grease and wax or plastic sheathing fulfil this function.
Grout has two main tasks in a bonded tendon:

- To protect the prestressing steel from corrosion.
- To provide the necessary bond between the strands and the structure member, in accordance with the design.

Cementitious grout provides excellent protection for

Top of page: Full scale testing of new grouting procedures. Bottom: Examples of tests for extended performance and height.






prestressing steel, thanks to the highly alkaline environment which passivates it against corrosion. All the analysis demonstrates that the vast majority of PT structures have behaved satisfactorily – demonstrating excellent durability of the post-tensioning tendons with, at the very least, good design principles and best practice installation techniques. However, enough deficiencies were found to prompt a review of the quality of the grout specified for use – but most of all, of the grouting practice itself.

QUALITY BBR GROUT

Throughout the years, the BBR experts have been working to produce a truly remarkable grout in terms of quality – using prime products in the market, leading equipment and grouting technology.

This has made it possible for our grout and grouting process to be fully compliant with all of the demanding requirements contained within the new standards – even long before they came into force. The BBR Network was so conscious of the importance of this aspect, that most grout tests – which nowadays are compulsory – had, for some years, already been conducted on most projects as a BBR internal requirement.

Whilst no single protection layer will guarantee durability, a good quality grout and good grouting practice are of prime importance for the robustness of any post-tensioning installation. Grout can provide excellent protection for post-tensioned structures – even more than any other protection layer – and this vital tool is in our hands!

FOURTH LNG TANK, CARTAGENA, SPAIN

Special grouting operation

The fourth tank in Cartagena is a 40m high, 78m diameter cylindrical concrete tank constructed to store Liquefied Natural Gas (LNG). David Olivares Latorre of **BBR PTE** – the BBR Network member in Spain – reports that, in total, more than 600,000kg of post-tensioning steel, for both vertical and horizontal tendons, was used for the project.

The prestressing system used was 0.6" diameter BBR CONA for cables with 15, 19 and 24 strands.

The interior prestressing consisted of:

- three foundation slab rings – 24 M2406 anchorages in 135m tendons
- cylinder horizontal wall – 288 M1506 anchorages in 130m tendons
- cylinder vertical wall – 144 loops with over 90m in each and 272 M1906 anchorages.

PT DESIGN

Foundation slab rings consist of horizontal tendons made with galvanized duct. Meanwhile, the vertical loops have an inferior curve also made of galvanized duct – and the remainder of the vertical straight design consists of 8m of 104mm diameter rigid ducts connected to each other by male-female ends. In addition, each joint is covered with a thermo-shrinking sleeve.

STRAND PUSHING

Horizontal cables were pushed by hanging the strand pushing machine from a crane while the operators were on an elevated platform. The pushing machine was tied onto the tank to keep it stable. Meanwhile, the vertical cable loops were pushed by means of a flexible duct situated between the M1906 anchorage and the pushing machine.

SEQUENCED STRESSING

The foundation slab rings were stressed before construction of the tank. Stressing of the remaining tendons was carried out in sequence with construction because of the forces applied to the structure. The agreed sequence began with the stressing of some horizontal tendons and the next stage was to stress the first half of the vertical loops. Afterwards, half of the horizontal tendons were stressed before the second half of the vertical tendons. Finally, the lowest horizontal cables, beside the access doors, were stressed.

GROUTING OPERATION

When considering corrosion protection of the cables, our main concern was the grouting of the 40m high vertical loop tendons. We decided to use a special grout – specified in ETAG-013 clause c.4.3 – combined with a specific method for the grouting of vertical tendons.

The chosen grout was made with Portland cement I-42.5, thixotropic admixture and water (w/c=0.44). In addition to the standard tests for grout, we constructed a battery of inclined tube tests and wick-induced tests to demonstrate the suitability of the grout – and obtained excellent results in terms of bleeding, change of volume and workability.

The specific method designed for vertical tendons was the wringing method which involves forced bleeding of the grout to force water out of the tendon and through the wires of the strands at the upper anchor head. The result is the complete elimination of any possible water seepage at the top of the tendons.

ADRIATIC LNG TERMINAL SPAIN-ITALY

Shared experience

As reported in the last edition of CONNAECT, the world's first offshore LNG terminal – the Isola di Porto Levante terminal – has been under construction in a dry dock near Algeçiras, Spain. Andrés Soriano of **BBR PTE** now brings us a further report about the project as it nears completion and how his company's earlier experiences combined with best-in-class BBR technology to steer the best solution for the challenge.

"SHARING THE BBR PTE TEAM'S EXPERIENCE ... HAS BEEN THE MOST IMPORTANT CONTRIBUTION WE HAVE MADE ON THIS CURRENT CONTRACT."

This 180m long gravity-based structure will be towed, when complete, to its intended offshore location – in 30m deep Adriatic waters, 17km from the Italian mainland, between Venice and Punta della Maestra in Rovigo. BBR PTE has been working on this project as part of a joint venture – PT Adriático UTE – which is tasked with post-tensioning works for the scheme.

INNOVATIVE TECHNOLOGY

Construction of this unique gravity-based structure has employed innovative technology – and approaching 4,000t of prestressing steel! BBR CONA anchorages were installed in a number of horizontal tendons. In all vertical loop tendons BBR rigid ducting was used.
The threading of the cables was carried out strand-by-strand, even for the vertical loops. Special grout, as specified in ETAG 013, was used – and full-scale tests (horizontal and vertical) were carried out prior to starting field grouting. Thixotropic grout was used for the horizontal and vertical tendons.

THE MONACO Challenge

The huge floating breakwater, made in Spain for the Government of Monaco, was designed to expand the principality into the sea and double the size of its La Condamine Port, making it possible for large cruise liners to dock. The completed wharf has four levels, a storage area for boats and a multi-storey car park as well as several shops and restaurants. This innovative construction project which had a 100-year lifetime requirement was carried out as two separate contracts – one for the fixed structure and another for the floating breakwater. The latter contract was secured by a consortium including FCC Construccion – and for which BBR PTE carried out the challenging post-tensioning work. In 2006, the project was recognised as an "Outstanding Concrete Structure" through a prestigious award from fib (The International Federation for Structural Concrete).

Facts & Figures

Horizontal tendons

TYPE 19, 0.6" DIAMETER

◆ Galvanized sheath	147,370m
◆ Slabs	1,706t
◆ Walls	1,183t
◆ Beams	192t

Vertical tendons

TYPE 19, 0.6" DIAMETER
& TYPE 12 0.6" DIAMETER

Rigid tubes	44,183m
Loops	769t

Prestressing steel

Total quantity	3,850t

For the grouting of vertical cables, the wringing method was used – in combination with the sucking out and flushing method. However, for the horizontal cables the vacuum method was chosen. This obviated the need to use intermediate vents – which would have been a major challenge, as access was very difficult. This method was proposed by BBR PTE, based on our experience on the award-winning Monaco Floating Breakwater project – built some years ago, in the same dock (see adjacent story). Sharing the BBR PTE team's experience on the latter project and also the post-tensioning of a number of LNG tanks throughout Spain has been the most important contribution we have made on this current contract.

The Adriatic LNG Terminal contains two nickel-steel LNG storage tanks with a total working capacity of 250.000m^3, approximately twice the capacity of a typical LNG carrying ship.

NETWORK STRENGTH

The long experience and expertise of Norwegian BBR Network member, KB Spennteknikk, in providing bearings to enable flexible nodes for international offshore applications was harnessed for the Adriatic LNG project. A total of 53 special marine TOBE pot bearings were designed and produced in Norway and transported to Algeçiras for installation. The fixed bearings are manufactured from the highest quality steel and designed to endure the harsh marine environment, as well as being capable of withstanding loads from earthquakes and blast events. The main construction work has now been completed and the terminal is expected to be floated in July 2008. ●

TEAM & TECHNOLOGY

OWNER
ExxonMobil (45%), Qatar Petroleum (45%) and Edison (10%)

CONTRACTOR
Aker Kvaerner

DESIGNER
Aker Kvaerner

GBS CONTRACTOR
Acciona Infraestructuras, S.A.

PT SUBCONTRACTOR
BBR PTE, within PT Adriatico UTE Joint Venture

TECHNOLOGY
BBR CONA internal

BBR NETWORK MEMBER
BBR Pretensados y Técnicas Especiales (Spain)

Towering success

RETENUE DES BLANCHETS, LA PLAGNE, FRANCE

This tower was built within the scope of a water reservoir construction project – high in the mountains, at an altitude of 2,400m. The project was completed between May and August 2007. The structure was erected using 15 prefabricated concrete elements – each was 1350mm high and had a 2350mm diameter. The segments were installed with the help of a crane and using special mortar. After the erection of the tower, 16 vertical BBR VT CONA CMI 0.406 cables were tensioned and injected with high performance grout. ●

TEAM & TECHNOLOGY

OWNER
SIGP – Syndicat Intercommunal de la Grande Plagne

CONTRACTOR
ISL – Company : SOCCO and OSC

TECHNOLOGY
BBR VT CONA CMI internal

BBR NETWORK MEMBER
ETIC (France)

WATER TREATMENT TANKS, AUSTRALIA

Purifying Queensland's Water

The Queensland Government has invested heavily in upgrades to various waste water treatment plants within the Brisbane, Mackay and Gold Coast areas. Work includes upgrades to the existing plants with the construction of new cast in-situ feed tanks and precast bioreactor and clarifier tanks. BBR Network member **Structural Systems** was contracted to provide installation and stressing to all associated post-tensioned works – Justin Hampton talks us through the project.

IN SITU TANK CONSTRUCTION

Large rectangular base slabs were designed with post-tensioning to minimise the requirement for joints in the large raw feed tanks. This ensured that the structure could be adequately water-proofed and reduced the amount of flexible water-stops at joint locations. Post-tensioning of the base slab also reduced the likelihood of cracking, minimising any environmental damage caused by the leaking of dangerous raw sewage into the ground water system. Larger pour sizes also allowed for an acceleration of the works programme.

PRE-CAST TANKS

Circular precast tanks were chosen for their speed of construction and reduced quantities of falsework required. This resulted in minimal disruption to the plant work areas – which was paramount, as each plant was fully operational during the construction phase.

Two types of precast tanks were constructed. The bioreactor tanks were 85m in diameter and 6.5m in height and required ten 706 tendons. The clarifier tanks were 50m in diameter and 5.4m high and required seven 705 tendons. Each precast element was formed and poured off site, with an average panel width of 3.42m.

Between the precast panels, a 600mm stitch joint was left which was formed and poured

conventionally. Tendon ducting was coupled within the stitches to ensure continuity of the tendons. Once all the stitches were poured, strand was pushed into each ducting void.

The tank panels sat on rubber pads, which allowed movement at the base, to reduce any likelihood of restraint from drying and compression effects.

Precast tank construction allows for quick site construction – and is particularly effective in remote areas where equipment and material supply is difficult. This also reduces complications which arise from remote concrete batching requirements for single tank construction.

SYSTEM SELECTION

One of the keys to this successful project was deciding on a construction system that was economical, quick to construct and ensured that impact on the local environment was minimised. The project demanded a solution that would enhance the long term durability of the structure, as well as minimise long term maintenance issues. Post-tensioned construction was the obvious choice. A total of nine pre-cast tanks and six in-situ concrete tanks have been constructed throughout Queensland using the bonded BBR CONA flat and BBR CONA internal anchorage systems.

BENEFITS

Structural Systems was contracted to supply and install the post-tensioning systems for all tank structures. Post-tensioning was chosen for both economic and structural benefits, allowing for reduced slab thicknesses in the base slabs and thinner walls in the circular pre-cast tanks than would exist with a conventional reinforced solution.

TEAM & TECHNOLOGY

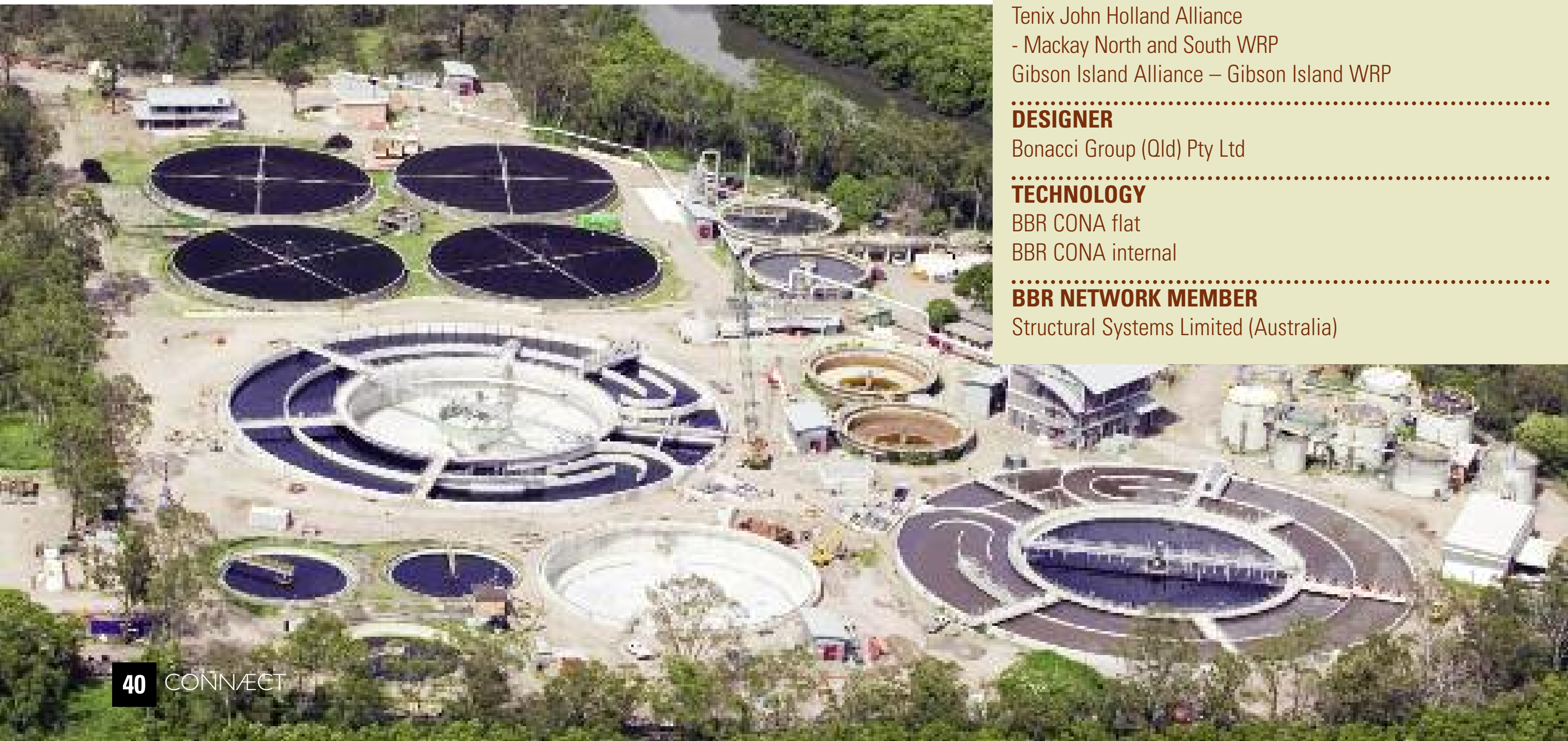
OWNER
Queensland Government

ALLIANCE CONTRACTORS
BWEA Alliance – Oxley, Sandgate and Wynnum WWTP
Waterfuture – Merrimac WWTP
Tenix John Holland Alliance
- Mackay North and South WRP
Gibson Island Alliance – Gibson Island WRP

DESIGNER
Bonacci Group (Qld) Pty Ltd

TECHNOLOGY
BBR CONA flat
BBR CONA internal

BBR NETWORK MEMBER
Structural Systems Limited (Australia)



RENAISSANCE IN THE NUCLEAR POWER INDUSTRY

Energised FOR THE FUTURE

Since the epic failure, in 1979, at the nuclear plant on Three Mile Island (TMI), Pennsylvania – and indeed the Chernobyl disaster in 1986 – many lessons have been learned. One of these is about the importance of strong nuclear containment vessels, as the strength of the structure at TMI potentially prevented a greater disaster. With increasing pressures to slow climate change, governments around the globe are now showing interest in commissioning new nuclear plants. We examine the shape of the current market, contemporary nuclear vessel design and practice – as well as the BBR Network's range of nuclear products and capabilities. ➔

The **global** picture

Nuclear technology was first developed in the 1940s and uses the energy released by splitting the atoms of certain elements. Research initially focused, during the Second World War, on producing bombs by splitting either uranium or plutonium atoms. It was only in the 1950s that attention turned to the peaceful purposes of nuclear fission, notably for power generation. Today, the world produces as much electricity from nuclear energy as it did from all sources combined in 1960.

Civil nuclear power now supplies 16% of global needs, in 30 countries – which together have some 439 commercial nuclear power reactors. Over 30 further power reactors are under construction, equivalent to 7.5% of existing capacity, while over 80 are firmly planned, equivalent to 24% of present capacity.

Sixteen countries depend on nuclear power for at least a quarter of their electricity. France and Lithuania obtain around three quarters of their power from nuclear energy, while Belgium, Bulgaria, Hungary, Slovakia, South Korea, Sweden, Switzerland, Slovenia and Ukraine get one third or more. Japan, Germany and Finland get more than a quarter of their power from nuclear energy, while the USA gets almost one fifth.

COUNTRY	NUMBER OF NUCLEAR REACTORS			
	OPERABLE	UNDER CONSTRUCTION	PLANNED	PROPOSED
Argentina	2	1	1	1
Armenia	1	0	0	1
Bangladesh	0	0	0	2
Belarus	0	0	2	0
Belgium	7	0	0	0
Brazil	2	0	1	4
Bulgaria	2	0	2	0
Canada	18	2	4	2
China	11	5	30	86
Czech Republic	6	0	0	2
Egypt	0	0	0	1
Finland	4	1	0	1
France	59	1	0	1
Germany	17	0	0	0
Hungary	4	0	0	2
India	17	6	10	9
Indonesia	0	0	2	0
Iran	0	1	2	1
Israel	0	0	0	1
Japan	55	2	11	1
Kazakhstan	0	0	0	1
Korea DPR (North)	0	0	1	0
Korea RO (South)	20	2	6	0
Lithuania	1	0	0	2
Mexico	2	0	0	2
Netherlands	1	0	0	0
Pakistan	2	1	2	2
Romania	2	0	2	1
Russia	31	7	8	20
Slovakia	5	2	0	0
Slovenia	1	0	0	1
South Africa	2	0	1	24
Spain	8	0	0	0
Sweden	10	0	0	0
Switzerland	5	0	0	1
Thailand	0	0	0	4
Turkey	0	0	0	3
Ukraine	15	0	2	20
United Kingdom	19	0	0	0
USA	104	0	7	25
Vietnam	0	0	0	2
WORLD	439	33	94	222

Source: World Nuclear Organisation, October 2007

WORLD ENERGY DEMAND

From 1980 to 2004, total world primary energy demand grew by 54% – and to 2030, it is projected to grow at much the same rate.

Electricity growth is even stronger, and is projected to almost double from 2004 to 2030. Increased demand is most dramatic in developing countries – and that is projected to increase. Currently some two billion people have no access to electricity and remedying this lack is a high priority.

With the United Nations predicting world population growth from 6.4 billion in 2004 to 8.1 billion by 2030, demand for energy must increase substantially over that period. Both population growth and increasing standards of living for many people in developing countries will cause strong growth in energy demand.

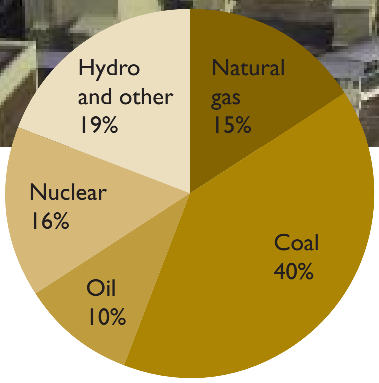
MEETING FUTURE NEEDS

Nuclear power generation is an established part of the world's electricity mix and is especially suitable for large-scale, base-load electricity demand.

The World Energy Outlook 2006 from the OECD's International Energy Agency (IEA) highlights the increasing importance of nuclear power in meeting energy needs while achieving security of supply and minimising carbon dioxide emissions. The report demonstrates that nuclear power could make a major contribution to reducing dependence on imported gas and curbing CO2 emissions in a cost-effective way, since uranium fuel is abundant.

CURBING GREENHOUSE GASES

On a global scale, nuclear power currently reduces carbon dioxide emissions by some 2.5 billion tonnes per year. Carbon dioxide accounts



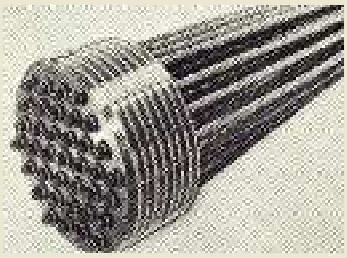
for half of the human-contributed portion of the global warming effect of the atmosphere – over one-third of human-induced greenhouse gases come from the burning of fossil fuel to generate electricity. Nuclear power plants do not emit these gases. In 2007, the UN Intergovernment Panel on Climate Change (IPPC) produced a report on mitigation of climate change which says that the most cost-effective option for restricting the temperature rise to under 3°C will require an increase in non-carbon electricity generation from 34% (nuclear plus hydro) now to 48 – 53% by 2030, along with other measures. With a doubling of overall electricity demand by then, and a carbon emission cost of US$ 50 per tonne of CO_2, nuclear's share of electricity generation is projected by IPCC to grow from 16% now to 18% of the increased demand, representing more than a doubling of the current nuclear output by 2030. These projected figures are estimates, and it is evident that if the renewable energy sector – such as solar, wind and water power – fails to grow as much as hoped, it means that other non-carbon sources will need to play a larger role. Thus nuclear power's contribution could triple or perhaps quadruple to more than 30% of the global generation mix in 2030.

Pioneering BBR **spirit**

BBR engineers were pioneers in the truest sense of the word when it came to developing high capacity tendons for nuclear applications. As early as the 1960s, they tested the first generation of large tendons for nuclear power plants – BBR wire tendons with button heads and BBR strand tendons with wedges.

This early BBR testing of tendons involved the construction of a special facility at the tendon assembly plant in Switzerland, in order that large tendons could be tested in conditions which

Full-scale grouting and replacement test with tendons consisting of 7mm diameter wires in tightly twisted groups of three wires each, as well as with tendons composed of strands.



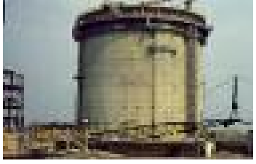
simulated the environment of a reactor vessel.

Although in the sixties, at the beginning of this new application, some pressure vessels had been realised with tendons which are today considered quite small, the use of large capacity tendons soon became common practice.

Since 1965, prestressing by post–tensioning has become a clearly established technique for pressure confinement in the nuclear power industry.

Today, the recognised adaptability and reliability of BBR Prestressing Systems for the post-tensioning of nuclear power plant pressure and containment vessels has made them some of the best known internationally. The BBR team has now completed close to 100 nuclear energy projects in 15 countries.

ABOVE: Construction of bottom cap with buttresses for anchorages of the UK's Dungeness B pressure vessel. BELOW: Testing of BBR anchor head. Stressing device consists of three 500t jacks, hydraulic pumps and load cells.

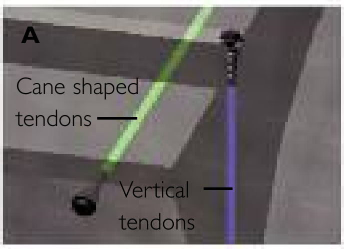


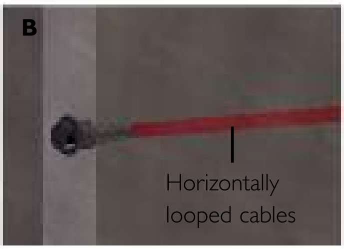


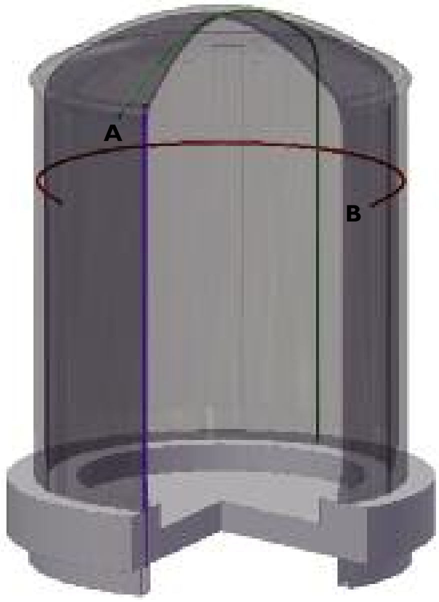
Contemporary
NUCLEAR VESSEL DESIGN

In nearly all projects, the basic structural design is a cylindrical vessel with flat end slabs or a convex dome. Practically all recent nuclear structures consist typically of two shells, the inner and the outer containment.

Today, the post-tensioned nuclear structures have reached an outside diameter of 50m and a height of 70m of the inner shell with a capacity of 1600MW.







BBR PT TENDONS

Three types of BBR post-tensioning tendons are typically used the inner containment, as follows:

- **Vertical tendons for wall post-tensioning**
  The lower anchorage is situated in the roof of the tendon gallery and the higher anchorage is placed on the ring in the base level of the dome.
- **Horizontally looped tendons (hoop tendons)**
  These can accommodate a varying number of vertical buttresses (ribs) – for example, four buttresses with 180° tendon hoops or three buttresses with 240° tendon hoops. The tendons are anchored alternately in one of the vertical ribs and both anchorages are situated on opposite sides of the same rib. The current trend is to reduce the number of buttresses.
- **Horizontal end slab post-tensioning "cane shaped" tendons**
  These are placed in two right angled planes in the dome, which have a varying length. The lower anchorage is situated in the roof of the PT gallery and the upper anchorage is placed under the retaining ring of the dome.

BBR PROTECTION

During the entire lifetime of the pressure vessels, the greatest attention must be paid to the protection of the prestressing steel from corrosion. The BBR Network uses three different types of corrosion protection for nuclear tendons:

- **Cement grouted tendons**
  The cementitious grout surrounds the prestressing steel in an alkaline environment that inhibits corrosion. If there is a local fracture of a tendon, part of the prestressing force remains transmitted to the concrete due to the bond with the grout. However, grouted tendons cannot be visually inspected, mechanically tested or retensioned in the event of greater than expected loss of prestress.
- **Grease or wax grouted tendons**
  For these unbonded tendons, the prestressing force is transmitted to the concrete primarily at the location of the anchorages. Corrosion is prevented by grease, corrosion-inhibiting compounds or wax. The tendons can be mechanically tested in-situ and the actual prestressing force can be monitored by lift-off tests or through permanently installed equipment. They can be retensioned and they can also be removed for visual inspection and eventually replaced.
- **Tendons protected with circulating dry air**
  For these unbonded tendons, the same properties and advantages apply as for the grease grouted tendons.

Spanish BBR Network member BBR PTE's grouting plant.

Periodical technical inspection of the tendons with lift-off tests at the Forsmark nuclear power plant in Sweden.

Inspection and **improvement work**

For the continuous safety of service of large tendons, accurate measurement of the stressing force and regular controls are of great importance. For many years now, BBR Network members have been carrying out lift-off tests and the experience of Norwegian BBR Network member, Spenntekknik, is typical – managing director, Tommy Lindstrand describes the work at a number of nuclear energy installations in Scandinavia.

Our periodical surveillance procedure is as follows:

- Lift-off of the anchor head with the BBR SA 500 automatic stressing device to determine the actual prestressing force – this is digitally recorded by an x-y-writer.
- The tendon is subsequently released and a single tensile element is extracted for corrosion examination and further testing in the technical laboratory.
- A new single tensile element is installed and the tendon is stressed again to its original prestressing force.

Utilising the latest technology for monitoring prestressing force, all types of BBR VT CONA CMI anchorages can be equipped with the BBR WIGAring ELASTO force measuring system. It allows for long-term tensile force measurements with digital control, memory, WINDOWS compatible data files and printing facilities.

In addition, Spenntekknik has been assisting with the replacement of steam generators at one of the plants. This work requires a large hole to be cut in the one metre thick secondary containment wall. The BBR team removes both horizontal and vertical tendons before the cutting process – and destresses the wall on the opposite side to avoid unexpected forces developing in the wall – keeping it in balance – during the replacement work.

As well as preparing Risk Assessment and Health & Safety statements for each job, our staff have to undergo a three day training course which covers behaviour inside the special facility. They are carefully screened and personal radiation logs are maintained and provided by the owner.

NUCLEAR TESTING

With flying colours

The BBR VT CONA CMI system has passed all prescribed European Organisation for Technical Approvals (EOTA) tests with flying colours – and has even withstood more stringent voluntary testing commissioned by the dedicated BBR engineers.

From the very beginning, ever since the foundation of the BBR partnership in 1944, many hundreds of tests have been executed in different technical laboratories for the approval of various anchorage types in many countries. However, since 2002, BBR VT CONA CMI bonded post-tensioning anchorage types have been developed and tested extensively in accordance with standards set by EOTA – and have secured European Technical Approval.

Static load, resistance to fatigue and load transfer tests were completed successfully according to ETAG guidelines.

Although well in excess of the ETAG requirements, the team decided to go above **eight million load cycles** – already over four times more than required – in one additional voluntary test run. It was amazing that, even under these extremely hard conditions, the tendon endured this gruelling fatigue testing without any strands breaking.

It is worthy of note that these tests were carried out as part of the certification of the largest post-tensioning tendon ever to be tested to these guidelines – anywhere in the World. In addition, **a full scale installation, replacement and grouting test** was undertaken for the 6106, similar to the trials carried out on smaller tendons by BBR forefathers *(see Pioneering spirit, page 42)*.

Top: Arrangement of the displacement transducers on wedges and strands for the BBR VT CMI 6106 tendon.
Bottom: Control unit in static load test for the BBR VT CMI 6106 tendon.

THE ULTIMATE stay cable system

In the last edition of CONNÆCT, we delved into the history of BBR's stay cable products and experience – extending over almost 60 years and over 300 projects. In 1968, BBR completed the world's first strand stay cable application for the Olympic Stadium in Munich and, in this edition, we focus on the benefits and technical superiority of the BBR HiAm CONA parallel strand stay cable system.

In terms of whole life cost, this is simply the best product on the market, especially when combined with the expertise of the BBR Network. Its superior fatigue resistance – "HiAm" stands for high amplitude fatigue resistance – makes it attractive for the most challenging of projects and thus it appeals to engineers and clients alike. Designers and architects have welcomed, in particular, the compactness of the anchorage system, as it allows them greater scope to produce a structure which has sleeker lines and which appeals to the visual senses of all who use and gaze upon it.

STAY CABLE CONFIGURATION

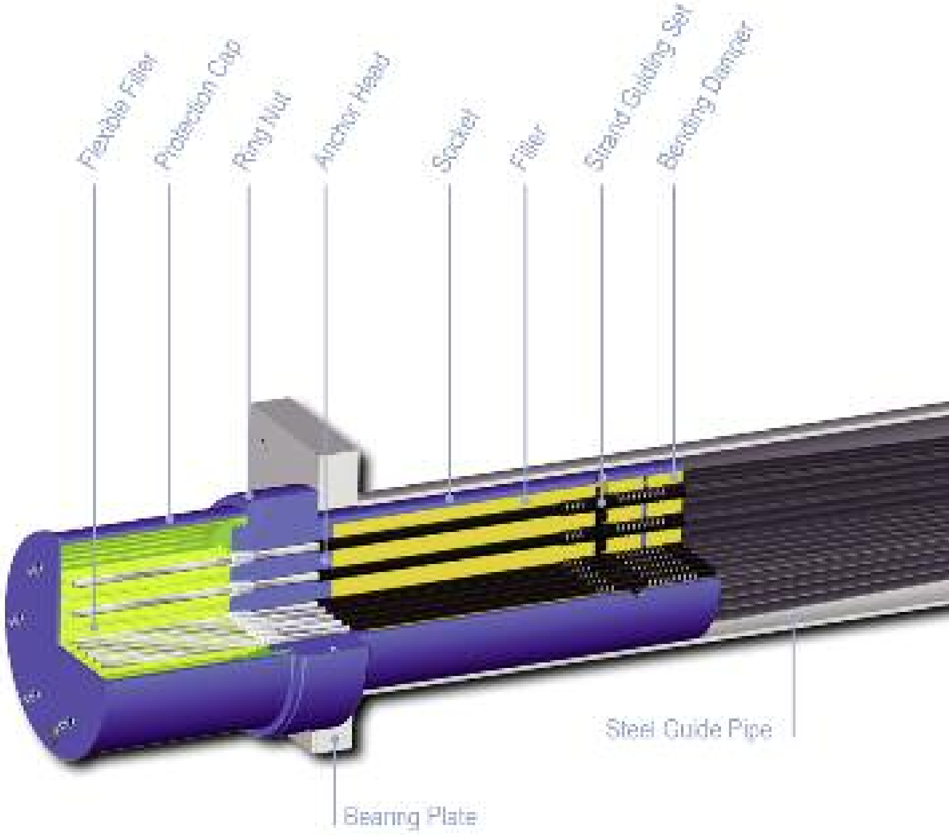
BBR HiAm CONA cables are made up of a compacted bundle of parallel seven-wire strands, enclosed in a ultraviolet-resistant high density polyethylene (HDPE) sheath of circular cross-section. The individual strands generally have a diameter of 0.62" and are of low relaxation grade, with a nominal cross-sectional area of 150mm^2 and a minimum guaranteed ultimate tensile stress of 1770N/mm^2 or 1860N/mm^2.
The strands are galvanised, greased or waxed and individually sheathed with a continuous and wear-resistant HDPE coating, providing each strand with an individual multilayer protection system. Alternatively, epoxy coated strands with a corresponding corrosion protection system, compacted strands with a cross-section of 165mm^2, or 0.6" diameter strands with 140mm^2 cross-section may also be used.

ANCHORAGE CONFIGURATION

In the anchorage zone, the strand bundle passes a deviator and spreads out towards the compact BBR HiAm CONA socket, where each strand is individually guided, sealed and locked. Ring nuts screwed onto the anchor heads transfer the cable loads, by contact pressure, to the supporting bearing plates. All anchorage components have been designed for a stress range greater than 300N/mm^2 – and to withstand the ultimate breaking load of the strand bundle with adequate safety.

STRESSING & MAINTENANCE

The BBR HiAm CONA system has been designed for single strand stressing or restressing, at any time during or after the installation, which means the system is easy to handle and requires significantly less equipment for stressing



operations. By the same token, maintenance is also easier as each individual strand can be inspected or replaced and additional strands can be added – saving time, costs and waste materials.
A unique feature of this system is that each strand is sealed off individually – and not only can the strand be inspected or replaced individually, but the sealing system can be inspected and replaced on an individual strand basis too.

BENDING DAMPER

In the anchorage socket, each strand is individually protected with a proprietary bending damper. Bending effects in cables may be introduced by excessive construction tolerances and cable vibrations.

COUNTERING CABLE VIBRATIONS

The short-term consequence of cable vibration is complaints from bridge users – the long-term consequence may be reduced safety factors or even failures of complete cables due to a rapid accumulation of bending fatigue stress cycles at the anchorages. Common phenomena which can cause cable vibration include:

- vortex shedding
- galloping
- parametric excitation – deck/pylon and cable interaction
- wind and rain-induced vibration.

Various countermeasures are available – for example, the use of a helical rib on the outside of the cable surface is particularly effective against wind-rain induced vibration. This prevents the formation of the coherent water rivulets which are responsible for the cable vibration and therefore mitigates the excitation at its source. Other cable surface treatments include dimples and longitudinal grooves. Cross-ties can be used to shift the natural frequencies of the cable stays and to avoid any possible interaction of deck and pylon with the stay cables. The use of cross-ties can also be an effective method for suppressing other types of cable vibration.
Supplemental devices can be used to add damping to the cable – hence achieving sufficient total damping as an efficient measure against cable vibration.
A proprietary and advanced cable damping solution is the BBR Square Damper which can be used internally or externally. The BBR Square Damper requires minimal maintenance and operates essentially in the same way as car brakes.

CERTIFICATION

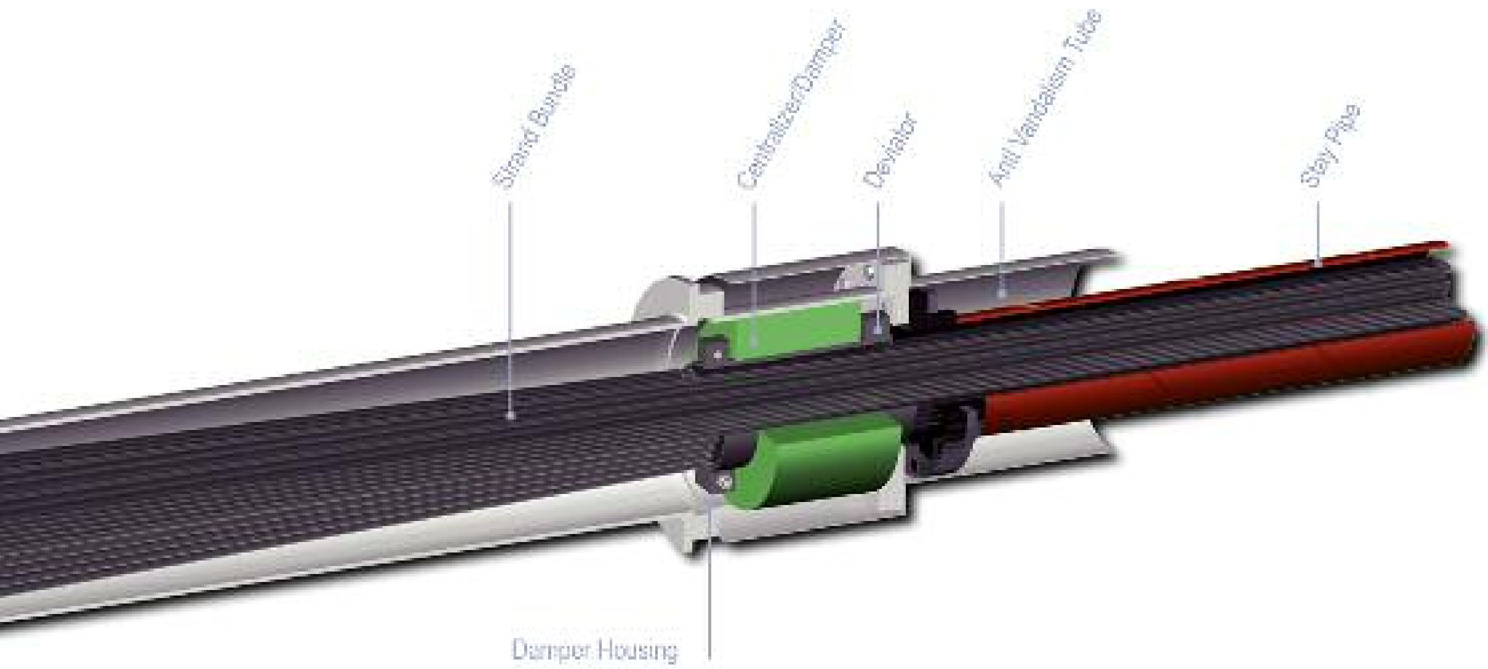
The BBR HiAm CONA stay cable system complies with the fib recommendation "Acceptance of stay cable systems using prestressing steels" as well as the corresponding PTI and SETRA recommendations.

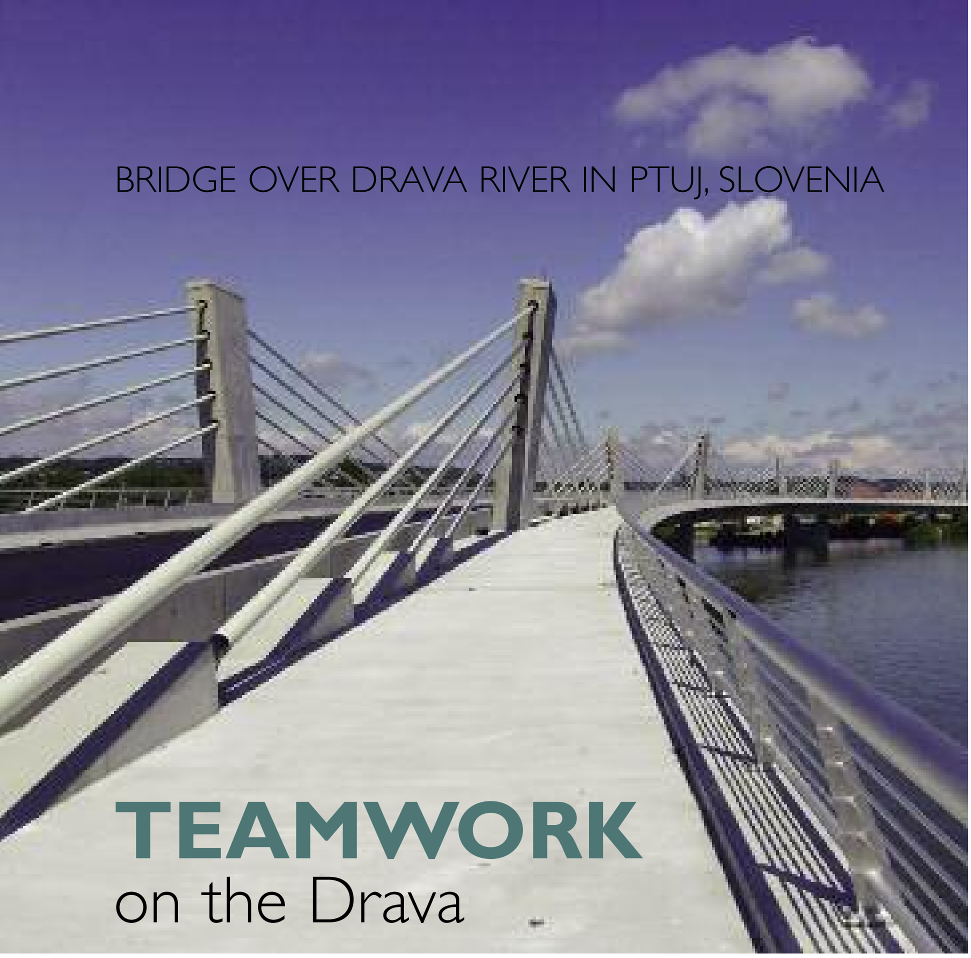
INSTALLATION

The installation of the BBR HiAm CONA system is typically performed on site using the strand-by-strand installation method which comprises four basic steps:

- Installation of the upper (pylon) and lower (deck) anchorages.
- The preassembled stay cable sheath is hung between the two anchorages using two master strands. The stay cable sheath is now used as a guide and passage from anchorage-to-anchorage.
- The strand is positioned at deck level, pulled up through the stay pipe and the upper anchorage, then inserted into the lower anchorage.
- Each strand is tensioned immediately after installation, using the BBR ISOSTRESS tensioning method, ensuring an equal stress distribution among the strands of an individual cable.

As an alternative to the single-strand installation method, fully or partially prefabricated cables can be installed and tensioned. The BBR HiAm CONA stay cable system is exclusively installed by teams of certified BBR PT Specialist Companies.





BRIDGE OVER DRAVA RIVER IN PTUJ, SLOVENIA

TEAMWORK
on the Drava

The Ptuj bypass road project required the construction of a bridge over the Drava River. The design concept was for a so-called "extradosed" bridge, as described by Rudolf Vierthaler of Austrian BBR Network member **VORSPANN-TECHNIK GmbH & Co. KG (VT),** who executed the project with BBR CONEX of Croatia.

At some 720km long, the River Drava is one of the longest rivers in Europe. On the journey from its source in the Italian Alps to Croatia, where it joins the River Danube, the Drava flows for around 102km through Slovenia and through the country's oldest city – Ptuj.
Until recently, motorists in the Ptuj area faced the daily frustration of traffic jams as they travelled across the city's only road bridge over the River Drava. It is, therefore, no surprise that local people were eagerly awaiting the opening of this new river bridge which forms part of the Hajdina-Ormoz expressway.

TEAM & TECHNOLOGY

OWNER
Dars d.d., Celje

CONTRACTOR
PORR d.o.o.

DESIGNER
Ponting d.o.o.

TECHNOLOGY
BBR VT CONA CMI internal

BBR NETWORK MEMBERS
VORSPANN-TECHNIK GmbH & Co. KG, (Austria)
BBR CONEX (Croatia)

BRIDGE STRUCTURE

The bridge structure is a continuous, 2.6m deep box-girder with three central spans – 100m centre span and two side spans of 65m, making a total length of 430m. The overall width of the bridge deck is 18.7m. In plan view, the bridge has a 460m radius curve.

CONSTRUCTION METHOD

The deck structure was erected by the free cantilever method and 5m long segments were cast in situ – the operation ran in parallel on both sides of the piers. The bridge is post-tensioned with both internal and external tendons.

POST-TENSIONING WORK

The BBR VT CONA CMI system was adopted for the internal tendons and the anchorages were installed and stressed by BBR CONEX.
The external tendons are VT 31-150 SK strand tendons and these were guided through deviator saddles on the 9m high pylons, then anchored underneath the deck slab outside the box-girder.

What is an extradosed bridge?

The structure of an extradosed bridge is often described as a cross between a box-girder bridge and a cable stayed bridge. However, unlike a cable stayed bridge, an extradosed bridge has a self-supporting deck.

Benefits that extradosed bridges might offer include:

- **longer spans** – in navigable watercourses, for example
- **reduced tower height** – in proximity to airports, for example
- **reduced girder depth** – enabling a longer span without impacting bridge deck profile

With a typical cable stayed bridge, most of the load – bridge deck, girders and traffic – is carried, through the cables, to the top of the towers and then down through the towers to the foundations. In an extradosed bridge, both the girders and the cables bear the load.

In an extradosed bridge, the deck is directly supported by resting on part of the tower – so that, in close proximity to the tower, the deck can act as a continuous beam.

The tension exerted by the cables acts more to compress the bridge deck horizontally than to support it vertically, because of the lower angles of intersection with the tower and deck involved. The cable stays thus act as prestressing cables for the concrete deck.

The end result is a highly efficient load-bearing bridge, with striking visual qualities offered by the exposed cables and concrete towers above the road surface.

The tendons comprise a bundle of 31 galvanised strands 150mm^2 1570/1770, greased and PE-coated, inside HDPE co-extruded duct. Co-extruded HDPE duct for stay cables combines the well-proven durability of black HDPE with the desire for architectural colouration and with improved thermal behaviour.
Assembly, installation, stressing and grouting works associated with the external tendons, were carried out with technical support from VT.
The external tendons were prefabricated on land, then installed and stressed as deck construction progressed. After stressing, the ducts were filled with cement grout.

STAY CABLES

MOTORWAY BRIDGE, LETENYE, HUNGARY

HUNGARY'S first extradosed bridge

Geometrical conditions dictated the design of an extradosed bridge for the junction of the M7 and M70 highways on the Becsehely-Letenye section, in south-western Hungary. Rudolf Vierthaler of VORSPANN-TECHNIK, the Austrian member of the BBR Network, gives details of this elegant solution.

The bridge structure is a continuous, 1.6m deep three-cell concrete box-girder with spans of 52.26m and 61.98m. The overall width of the bridge deck is 15.85m. The abutments are skewed to the bridge-axis at an angle of 60°, while the pier axis between is skewed at an angle of 40°.

POST-TENSIONING CONCEPT

Post-tensioning was undertaken using a combination of internal and external tendons. The internal tendons are strand tendons with 19 150mm^2 strands – four in each of the two inner longitudinal beams and six in each edge beam. The 125m long BBR VT CONA CMB external tendons run from abutment-to-abutment and are guided over deviators on the pylon and at transversal beams outside of the edge beams. The design of the abutment chamber allows easy control of the tendons and, if necessary, the adjustment of their force – or even their replacement. Load cells are installed for monitoring of the tendon forces.

EXTERNAL TENDON DEVIATORS

For the deviation of the external tendons, hollow steel profiles – bent to match the radius of the geometric shape – were installed in position before concreting. The deviators are designed to allow movement of the tendons by means of low friction sliding agents, such as Teflon and non-corrosive steel strips. The architectural design of the deviation points shows the statical system to best advantage. The external tendons were prefabricated in VT's factory in multiples of the required lengths, then they were installed and stressed after erection of the deck structure.

The engineers, whilst resolving the challenge of designing a bridge to suit the special geometrical conditions, devised a truly aesthetic solution which permits the function of the structural elements to be appreciated – and admired.

TEAM & TECHNOLOGY

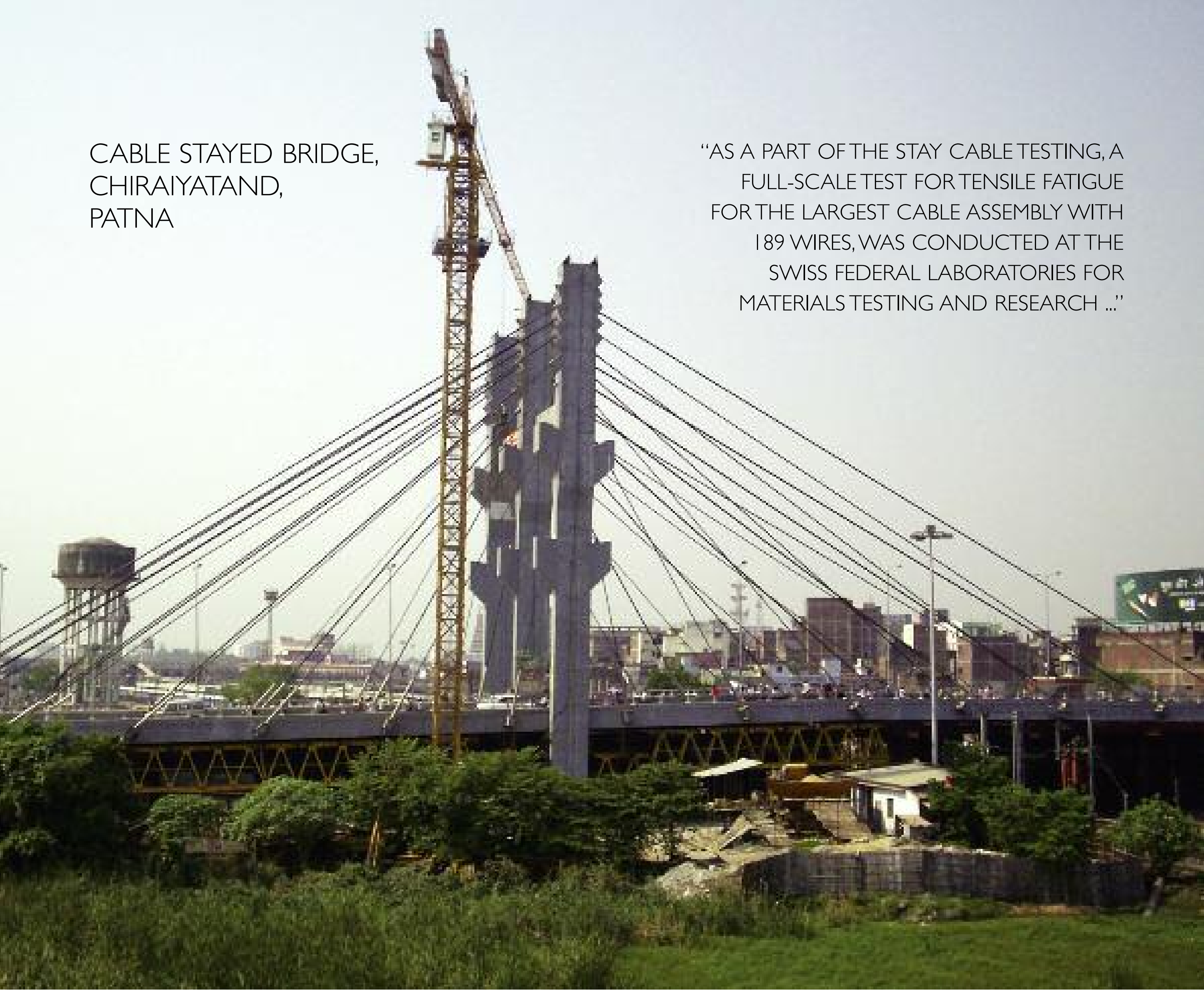
OWNER
National Highway Directorate, Budapest, Hungary

CONTRACTOR
Hídépitö Rt.

DESIGNER
Technical Department of Hídépitö Rt.

TECHNOLOGY
BBR VT CONA CMB band system

BBR NETWORK MEMBER
VORSPANN-TECHNIK GmbH & Co. KG (Austria)



CABLE STAYED BRIDGE, CHIRAIYATAND, PATNA

"AS A PART OF THE STAY CABLE TESTING, A FULL-SCALE TEST FOR TENSILE FATIGUE FOR THE LARGEST CABLE ASSEMBLY WITH 189 WIRES, WAS CONDUCTED AT THE SWISS FEDERAL LABORATORIES FOR MATERIALS TESTING AND RESEARCH ..."

This four lane cable stayed road overbridge has been constructed to replace an existing two lane bridge which connects the junctions at the southern end of Kankarbagh and northern end of Exhibition Road in Chiraiyatand, Patna, Gopinath Jonnadula, General Manager (Projects & Products) for **BBR (India) Pvt Ltd** reports that a cable stayed bridge solution was recommended for some very practical reasons.

ON TRACK in Patna

The choice of a cable stayed bridge meant that no pier supports would need to be constructed within the existing railway lines below – and, in addition, any future extensions to the railway tracks could be more easily accommodated.

BRIDGE OVERVIEW

The 110m long bridge has a span configuration of 65m for the main span and side spans of 45m, each with two individual decks and carrying two lanes. The stay cables are arranged in three parallel planes, with the central plane common to both carriage-ways. The pylon is a three legged H-frame with straight 40m high concrete pylons.
The 7.5m wide carriageway has a reinforced concrete deck with edge beams and diaphragms at 2m intervals. Steel outriggers are provided on either side of the deck to anchor the stay cables

CONSTRUCTION METHOD

As the bridge site is located within a heavily congested area and there was no possibility of traffic diversions, construction was programmed over two phases. The first phase consisted of constructing the first carriageway, with a two lane deck, which was commissioned for traffic and was then followed by the demolition of the existing bridge.
In the second phase, the second carriageway deck was constructed and integrated with bridge already commissioned.
Pylon and deck construction has been executed simultaneously and the complete deck was concreted on continuous scaffold, staging and shuttering, supported from the ground over the full span. The entire deck scaffold remained in position until stay cable stressing had been completed.

STAY CABLES

Since prefabricated, factory-assembled stay cables with three nested layers of corrosion protection were proposed for the construction, the BBR DINA stay cable system was adopted for the bridge. Various sizes of anchorages have been used, starting from DINA Type 42 to Type 102 for both outer pylons and Type 102 to Type 192 have been used for the inner pylons which are jointly supporting the two decks. The stay cables have been assembled with parallel galvanized wires to passive and stressing end anchorages and encased in HDPE pipe. The annular space between the wires and HDPE pipe is also protected with grease.

INSTALLATION AND STRESSING

The grease-filled, assembled stay cables were coiled in steel bobbins and transported on trailers from BBR India's workshop in Bangalore to the construction site at Patna – approximately 2000km away.
The cables were installed with the help of a tower crane to anchor the stressing ends located in the pylon anchor zone. Deviators guided the stay cables though the deck level steel riggers and they were then anchored with locknuts. A special pulling mechanism was connected to the stressing end anchorage to stress the stay cables in a sequence prescribed the project engineer.

BRIDGE INSTRUMENTATION

Strain gauge-type load cells – with capacities varying from 200MT to 500MT – have been installed at the dead end anchor heads of the stay cables. These measure forces in the cables during stressing and monitor the forces in the stay cables during the service of the structure. The embedment-type strain gauges, with range of 3000micf, are bonded to the inner surface of the deck, as well as to the pylons at various specified points. These also measure the stresses in the concrete during construction, as well as during the operational lifetime of the structure. The instruments are connected by armoured cables to a control panel, where the readings are shown and then stored on computer.

STAY CABLE TESTING

As a part of the stay cable testing, a full-scale test for tensile fatigue for the largest cable assembly with 189 wires, was conducted at the Swiss Federal Laboratories for Materials Testing and Research, Empa, Switzerland – according to recommendations of the Post Tensioning Institute (PTI).
The DINA stay cable specimen was fabricated at BBR India's Bangalore workshop and transported to Empa by air freight as a preassembled unit.
The test specimen was installed in a cable testing machine and load was applied to a maximum of 5177kN and minimum of 3799kN with force range of 1378kN, at a testing frequency of 4.2Hz. After completion of two million cycles, the test specimen satisfied the test recommendations of the PTI. This same specimen was subjected to static load testing as per PTI recommendations – again, the cable was successful.

TEAM & TECHNOLOGY

OWNER
Indian Railways

CONTRACTOR
M/S Ircon International Ltd

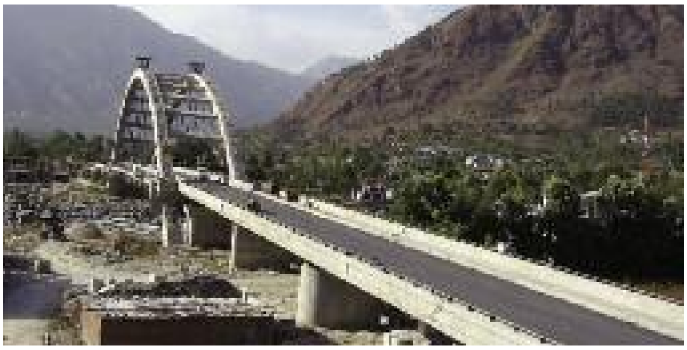
DESIGNER
M/S L&T Ramboll Consulting Engineers Ltd

TECHNOLOGY
BBR DINA stay

BBR NETWORK MEMBER
BBR (India) Pvt Ltd

PARVATI RIVER BRIDGE, HIMACHAL PRADESH, INDIA

FOOTHILLS OF **the Himalayas**



The Parvati River Bridge has been constructed in the picturesque location of India's Himachal Pradesh state, reports Mr B. Appa Rao, Deputy General Manager (Projects) for **BBR (India) Pvt Ltd.** This bridge connects Chandigarh with Manali tourist resort in the foothills of the great Himalayas.

The bridge consists of a 120m span and a 30m high two-rib arch for two-lane road traffic. The concrete arch was constructed with the help of a 35m high steel tower and BBRV temporary stays. The arch is divided into ten sections, including the starting stub. The remaining nine parts are cast, using steel form travellers, in nine stages. Each stage of casting is supported by one temporary stay cable from the temporary steel tower balanced with two pairs of BBRV temporary backstays located at the top and middle. The bottom backstays consist of 57 BBRV 7mm diameter cables and the top backstays consist of 80 BBRV 7mm diameter cables. These backstays are anchored to a heavy deadman at the adjoining pier. Similarly, the front temporary stays supporting the form travellers consist of 42 BBRV 7mm cables and 82 BBRV 7mm diameter cables. Supporting the bridge main deck are 13 reinforced concrete transverse beams which are, in turn, supported by 13 pairs of BBR DINA hangers spaced at 7.6m intervals. Each BBR DINA hanger consists of 75 high tensile 7mm steel wires in HDPE pipe. At the bridge deck level, DINA hangers are encased in steel trumpets for protection.

For this bridge, BBR India's challenge involved construction engineering and construction services, along with associated construction stage support – for example, design of temporary stays, steel tower, form traveller etc. We were responsible for the supply, erection and stressing of temporary stays and backstays – and indeed of the BBR DINA hangers.

TEAM & TECHNOLOGY

OWNER
M/S. PWD, Himchal Pradesh, India

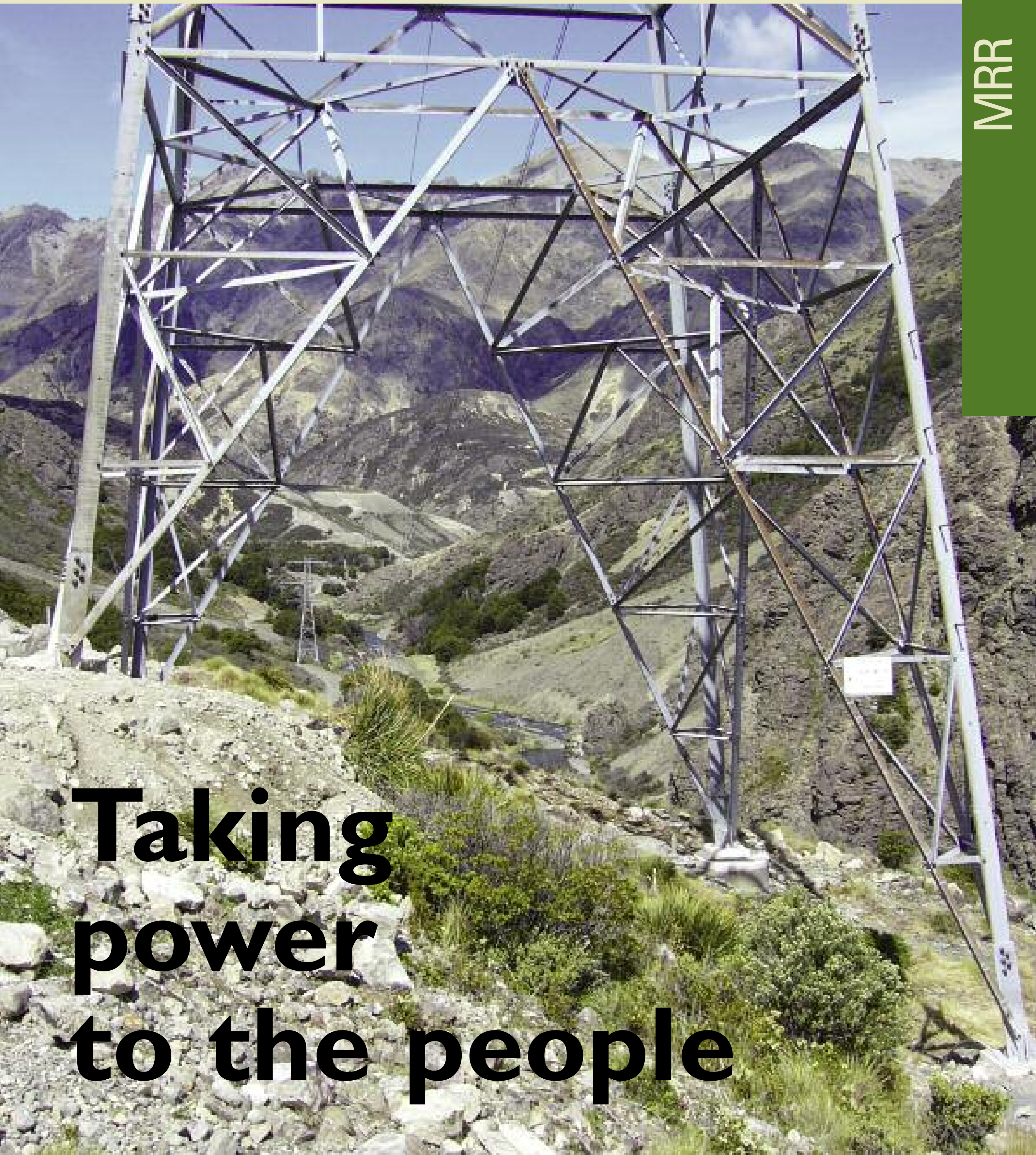
CONTRACTOR
M/S. V.K. Sood Engineers & Contractors, Haryana, India

DESIGNER
M/S. Tandon Consultants PVT Ltd
Construction Engineers, BBR (India) PVT Ltd

TECHNOLOGY
BBR DINA stay

BBR NETWORK MEMBER
BBR (India) Pvt Ltd

Supreme Winner of the prestigious New Zealand Engineering Excellence Awards 2007



Taking power to the people

TRANSMISSION TOWER FOUNDATION UPGRADE, UPPER SOUTH ISLAND, NEW ZEALAND

As the debate continues over the future and sustainability of New Zealand's energy supply, **BBR Contech** has been helping national grid operator Transpower, to ensure electricity continues to reach businesses and households throughout the country. ➔

The company has been working on strengthening the foundations of towers on the Transpower transmission line which runs from the Islington substation, near Christchurch, to the Kikiwa substation, near St Arnaud – the ISL-KIK "B" 220kV line – and the line running between the Blenheim and Stoke substations in the upper South Island – the BLN-STK "A" 110kV line.

UPGRADE LOADING

The lines were originally installed in the late 1970s with a single conductor circuit on one side of the towers. This new work involved stringing the second circuit and earth wire which increased the loads on the existing foundations. BBR Contech was engaged to strengthen those foundations which would be overloaded following the upgrades. In total, 160 towers were identified as requiring strengthening – 88 between Hanmer Springs and St Arnaud, 11 between Ashley and Waipara in North Canterbury and 61 between Blenheim and Stoke. All up, a workface extending some 300km!

LANDSCAPE CHALLENGES

As you can imagine, this was no easy project! The towers were located in a vast landscape with a huge diversity of topography, climatic conditions and underlying ground quality. Access was also limited and often extremely difficult, demanding an innovative construction approach which minimised the size of construction equipment and the quantity of materials while maximising the towers' lateral stability and earthquake resistance.

LIVE ENVIRONMENT

Added complications included the issues of working in a live transmission environment, dealing with a wide range of landowners – private owners, the Department of Conservation and commercial businesses – working around natural and man-made features, and complying with environment requirements.

EXPERIENCE TRIUMPHS

Fortunately, BBR Contech's previous experience of similar projects on the North Island provided

Supreme winner

BBR Contech has been presented with the 2007 New Zealand Engineering Excellence Awards Supreme Winner Award – the combined Transpower and BBR Contech team is pictured above, with Peter Higgins, BBR Contech Southern Regional Manager holding the award. On the same evening, they were also presented with a second award for their work, in the category Utilities, Networks and Amenities.

The grid upgrade project scored highly on all judging criteria, and the judges unanimously agreed it was a truly excellent example of engineering at its best. "The integrity of the power grid is vital to New Zealand's economy, and the project was clearly of significant national importance," said David Elms DistFIPENZ, Convenor of the Category Awards judging panel. He said the judges were particularly impressed by the calibre of both the technical and logistical management over an extended site.

The New Zealand Engineering Excellence Awards are hosted by a consortium of five partners and ten contributing organisations. The partners are: Centre for Advanced Engineering (CAE); Association of Local Government Engineering New Zealand Incorporated (INGENIUM); Electricity Engineers Association of New Zealand (EEA); Association of Consulting Engineers New Zealand (ACENZ); and the Institution of Professional Engineers New Zealand Inc (IPENZ).

TEAM & TECHNOLOGY

OWNER
Transpower NZ Ltd

CONTRACTOR
BBR Contech

DESIGNER
Transpower NZ Ltd
Powlesland Consulting Ltd (structural expert)
Pacific Geotech Ltd (geotechnical expert)

TECHNOLOGY
MRR range

BBR NETWORK MEMBER
BBR Contech (New Zealand)

Concrete Technology Award

BBR Contech has scooped the Technology Award at the annual New Zealand Concrete Society Conference for their work for national grid operator Transpower to strengthen the foundations of electricity transmission pylons enabling them to take additional loads. Pictured here is (right) Paul Wymer, Managing Director of BBR Contech accepting the award from Chris Munn, President of the New Zealand Concrete Society. The Technology Award is given to a project in recognition of outstanding innovation in the advancement of concrete practice in design, construction, rehabilitation or research.

"THE KEY TO SUCCESS WAS, OF COURSE, EFFECTIVE CO-ORDINATION AND COMMUNICATION – ALONG WITH SPECIALIST EXPERTISE, PROFESSIONALISM, GOODWILL AND TRUST AMONG ALL THE PARTIES."

us with a useful starting point, helping us to shape an approach that ensured cost-effective methods, proven strength enhancements to the towers, minimal interruption and disruption for landowners and the environment – and a project that we delivered on time.

WAY FORWARD

Appointed as head contractor and providing most of the personnel for the physical works, BBR Contech worked closely with Transpower and its expert technical advisers, along with structural, geotechnical, design, drilling, concreting and conservation experts to help configure a design and construction methodology that could be tested and completed in a relatively short timeframe. This involved:

- for towers requiring maximum uplift resistance – installing high-capacity post-tensioned ground anchors with double corrosion protection
- for towers requiring moderate uplift resistance – installing self-drilling ground anchors with grout encapsulation, and passive low-capacity soil anchors
- for towers requiring low-to-moderate uplift resistance – pressure grout enhancement to existing piles using tube-a-manchette techniques.

The key to success was, of course, effective co-ordination and communication – along with specialist expertise, professionalism, goodwill and trust among all the parties.

Despite numerous changes to the original programme and many unexpected issues, the team delivered the project on time.

This achievement was recognised by both the Department of Conservation (DOC) and Transpower, with DOC applauding "the Contech guys" for their great attitudes and good systems.

WAREHOUSE REPAIR, STARACHOWICE, POLAND

BREAKDOWN recovery

Repair works to the workshop roof girders and frame supporting structures were carried out by **BBR Polska,** during the modernisation and development of the MAN STAR Trucks & Buses Ltd production plant in Starachowice.

The poor workmanship of the original construction and the overload carried during the past 30 years meant that the reinforced concrete girders in Workshop No. 9 were in bad shape structurally – they were even close to break down in some places. The dreadful condition was quite evident – there were visible scratches and cracks with displacement which were temporarily supported. However, the state of the concrete had to be thoroughly tested. This was done in situ by BBR Polska and using highly specialised methods – the tests were repeated throughout the repair process.

The strengthening works involved various repair techniques and materials – injection, composite bands with carbon fibre and resin, carbon fibre sheets, post-tensioning locally with BBR CONA external 106 tendons and bars.

A technical paper on the operation was presented by Tomasz Borsz – BBR Polska, site manager for the Starachowice project – during the Conference in Miedzyzdroje in May 2007.

Built almost 70 years ago, two aircraft hangars at the Whenuapai Airbase form the maintenance and repair hub for the Royal New Zealand Air Force's Hercules and Orion fleet. Used daily, these spectacular structures – rising to a height of 20m and spanning 67m in width – can accommodate at least two Hercules each.

Concrete CARBONATION REPAIRS

AIRBASE HANGAR REPAIRS, WHENUAPAI, NEW ZEALAND

Beca Consultants discovered that carbonation of the concrete had advanced throughout the front façade of both hangars, causing corrosion of the steel reinforcing bars and eventually spalling the concrete surrounding them. BBR Contech was called in to repair the damage, while ensuring 24-hour access for the aircraft. This access requirement and the sheer scale of the work required a lateral approach to scaffolding. The answer was found in the mobile "scissor" platform that had been used in Auckland's Vector Arena project. The largest of its kind in Australasia, the scaffold offers reach – it has a working height of 22m – and mobility, allowing it to be moved out of the way of incoming and outgoing aircraft.

The project involved the application of about 15m^3 of concrete to the hangar beams, struts and arches, once the reinforcing bars were prepared using ultra-high pressure, low-volume water-blasting. Once the repairs were complete, more than 800m^2 of a three-coat, elastomeric, anti-carbonation coating was applied – with the aim of protecting the hangars from atmospheric damage well into the future.

TEAM & TECHNOLOGY

OWNER
Royal New Zealand Air Force

CONTRACTOR
BBR Contech

DESIGNER
Beca Consultants

TECHNOLOGY
MRR range

BBR NETWORK MEMBER
BBR Contech (New Zealand)

UNDERPINNING PIER 7, MAKATOTE VIADUCT, NEW ZEALAND

Collaborative **challenge**

Located between Ohakune and National Park, the Makatote Viaduct is the third highest railway viaduct in New Zealand. Land instability and erosion resulted in Pier 7 of the Makatote Viaduct being vulnerable to foundation failure and was identified as the greatest risk to any of the structures on the New Zealand Railway Network by its owner ONTRACK.

Completed on 10 July 1908 and now close to 100 years old, the Makatote Viaduct has a total height of 78.6m. As part of the North Island Main Trunk Line (NIMT) the viaduct serves as a vital link between Wellington and Auckland. Regular rainfalls and seasonal melting water from the adjacent volcanically active alpine region eroded the river banks and exposed the toe of the upstream mass concrete footing of Pier 7.

SHAPING THE PROJECT

A project was put together by ONTRACK to underpin the vulnerable foundations. The project team faced demanding constraints and difficulties that had to be overcome to ensure a successful outcome for the project. The construction was, effectively, being undertaken inside a National Park with numerous environmental challenges – including undertaking construction in a rare blue duck habitat and in a pristine trout spawning stream. Most critically, there was a possibility that the construction activities might, in themselves, destabilise the viaduct.

EXTREME CONDITIONS

ONTRACK, Fulton Hogan Civil Ltd and specialist engineering consultants worked collaboratively based on a no-blame and best-for-project approach to successfully complete the $4.2m scheme between May 2006 and February 2007. This extremely challenging project to underpin the eroded pier foundation was undertaken in difficult topography and during extreme weather conditions.

PREFERRED SOLUTION

The preferred solution was underpinning of the two front footings by installing a large pile at each footing and spanning a large cross beam between piles to support the lattice tower legs and relieve load on the existing footings.

The proposed underpinning structure consisted of two 2m diameter bored concrete ➔

Stop press .....

Railway network owner **ONTRACK** has won two category awards in the New Zealand Engineering Excellence Awards 2007 – Building & Construction and Roads & Transport

piles, constructed to a depth of 38m below beam soffit level. The piles were spanned by a post-tensioned, cast-in-situ, bone-shaped concrete beam 38m long, 1.5m wide and 3m deep. The horizontal loads are transferred through three steel struts from the concrete cross beam to six ground anchors, which were installed in pairs and connected with a pre-cast concrete tie beam.

The overall project was very challenging for Fulton Hogan Civil Ltd and involved a significant amount of temporary works to deal with access, piling and falsework. BBR Contech was associated with two subcontract elements of the contract – the post–tensioned cross beam and ground anchoring.

PT CROSS BEAM

Work on the 38m long post-tensioned cross beam – which transfers the load from the tower legs to the piles – commenced once the down stream pile and pier were completed. The cross beam was post-tensioned with eight BBR CONA tendons with 19 12.7mm strands to a point slightly above load-balanced conditions. This is the biggest transfer beam ever constructed in New Zealand.

GROUND ANCHORS

Six 12m long 40mm diameter bar ground anchors were required to provide the lateral restraint to the new concrete cross beam. The anchors were drilled with temporary casing, using a down-the-hole hammer drill. Drilling through the andesite boulder material was difficult but all six anchors were installed within a tolerance of less than 50mm. This allowed for a smooth installation of the pre-fabricated concrete anchor head walls and tie beams which were fabricated off site.

The double corrosion-protected ground anchors were grouted and tested after curing to 75% UTS and locked off at 500kN. The tie back struts, consisting of 400mm diameter steel tubes, were then lifted into place to connect the main cross beam to the ground anchors.

PIONEERING SPIRIT

The construction of the Makatote Viaduct, a century ago, was a milestone in New Zealand railway construction and only written reports can provide us today with an insight of the challenges the construction pioneers encountered in this rugged alpine environment. Our team on the project experienced these challenges first-hand using today's technology, but can only marvel at what our pioneering engineers and construction teams achieved! The Makatote Viaduct project has taught the team involved that the most important ingredients for a successful project are the identification of risk and opportunity within the project, the determination of the people, open communication at all levels and a common goal.

TEAM & TECHNOLOGY

OWNER
ONTRACK

CONTRACTOR
Fulton Hogan Civil Ltd

DESIGNER
Novare Design Ltd

TECHNOLOGY
BBR CONA internal
Bar ground anchors

BBR NETWORK MEMBER
BBR Contech (New Zealand)

Timely solution IN LIVE TRAFFIC

BATU KITANG BRIDGE, SARAWAK, MALAYSIA

The bridge over the Batu Kitang River was built 40 years ago using welded steel plate girders and a composite deck slab. The retrofit and bridge widening project involved the widening of the piers and abutments, as well as the deck on either side of the existing structure, to provide two lanes of traffic in each direction. Before widening, the 40-year old bearings needed replacing – which is where **BBR Malaysia** was able to help.

The bridge has three spans – two 27m side spans and one central 40m span and fixed bearings are on one of the river piers. BBR Malaysia was engaged to replace the existing 16 steel rock bearings with laminated elastomeric bearings, as well as replacing the existing steel expansion joints. As the bridge was in constant daily use – mainly by heavily-laden vehicles carrying loads from the nearby quarry – the replacement works were both challenging and dangerous.

EXPERIENCED VIEW

The sequence of the replacement works commenced with Abutment A and then followed by Pier 1, next to Abutment B and finally moved onto Pier 2. At each pier or abutment, the adjacent bridge girders were not lifted up at the bearing locations – being a steel composite bridge, the girders are not very rigid.

BBR put forward the proposal based on experience of previous bearing replacement projects and leveraging on our experience of hydraulics and heavy lifting and our hydraulic jacks, pumps and accessories.

LIFTING OPERATIONS

The lifting operation utilised four of 250t "pancake" flat jacks, placed underneath each of the steel girders and rested on steel bearing plates on the concrete tops of the respective pier columns and abutments. These flat jacks lifted up the four girders at each support location simultaneously using hydraulic jacks. A single pump was used to distribute the hydraulic pressure to four separate jacks. A needle valve was installed before the jack, to control and fine tune the pressure going into each jack – because the forces on all four girders varied.

REPLACING BEARINGS

Steel plates were placed to cover the joint being lifted. After the girders were jacked up 25mm, the locking rings of the jacks were turned to hold up the bridge. A greased 15mm thick HDPE sheet was placed between the soffit of the girders and top of the jacks to allow horizontal expansion and contraction movements of the existing bridge while bearings were being replaced.

As the height between the soffit of the steel girder to the top of the concrete was approximately 250mm and the laminated elastomeric bearings only had a thickness 83.5mm and 99mm, the difference in height was made up by installing galvanised steel plates.

In spite of the tight schedule for sourcing of material and the huge amount of actual physical work to be carried out, the replacement works were successfully completed within the agreed three month programme.

TEAM & TECHNOLOGY

OWNER
Public Works Department of Malaysia

CONTRACTOR
Hart Builders Sdn Bhd

DESIGNER
TCS Consulting Engineers

TECHNOLOGY
Heavy Jacking System

BBR NETWORK MEMBER
BBR Construction Systems (M) Sdn Bhd (Malaysia)

ROSS RIVER DAM, TOWNSVILLE, AUSTRALIA

With many dams now requiring upgrading to meet revised safety standards, Mark Sinclair of BBR Network member **Structural Systems,** describes how they have recently completed permanent anchoring and trunnion restraint tendons to make the Ross River Dam secure for the local community.

The Ross River Dam is located 20km southwest of Townsville, Queensland and is not only the major water supply for Townsville and Thuringowa, but also protects these cities from flooding. The dam was built in 1971, with a catchment area of 750km^2 and a capacity of 219,000 mega litres. Beside the 30m high, 40m wide concrete spillway structure, the dam has an earth embankment of some 8km and averages a height of 27m.

SAFETY & CAPACITY

As a result of detailed investigation, with reference to local and international dam standards, the entire dam was deemed to need upgrading to achieve compliance at a cost of approximately US$70m. The improvements to the concrete spillway and installation of radial gates have increased capacity by 9% (+21,000 mega litres) providing an additional four months' water supply, as well as allowing better flood control. Significant embankment works, including 1,900,000m^3 of earthworks, have upgraded its safety to an acceptable level.

SPILLWAY UPGRADE

Upgrading the spillway involved lowering the crest some 3.8m and providing a new curved "ogee" crest to the original height. In addition, two new piers and three radial gates were fitted. Structural Systems has undertaken a significant share of Australian dam stabilisation projects – including the longest and largest capacity permanent anchors ever undertaken in Australia (91 x ø15.2 x 142.2m) at Canning Dam – and were the preferred choice of the client, JHMJV to undertake this critical work at the Ross River Dam. The company was engaged to complete nine permanent ground anchors – three in the

TEAM & TECHNOLOGY

OWNER
NQ Water

CONTRACTOR
John Holland & Macmahon Joint Venture

DESIGNER
GHD / MWH

TECHNOLOGY
BBR CONA permanent anchor
BBR CONA internal

BBR NETWORK MEMBER
Structural Systems Limited (Australia)

"ON CLOSE INSPECTION THE ANCHORAGE ZONES WERE 100% DRY, EVEN AFTER BEING SUBMERGED FOR A SIGNIFICANT TIME, CONFIRMING THEIR RELIABILITY, THE QUALITY OF THE SYSTEM AND THE WORKMANSHIP OF THE TEAM."

top of each of the three ogee crests – and around 13m spillway bays, plus additional post-tensioning work to tie back the radial gates, at the trunnion mounting, to two piers and two abutments.

ANCHORING WORKS

Anchoring works included the fabrication, transportation, installation, grouting, stressing and monitoring of the permanent ground anchors. The anchors were up to 54m long, each providing a force of 875t. An anchor consisted of 50 15.2mm strands, individually greased and sheathed over the free length allowing the strand to extend without restraint, while the remaining 11m of bare strand, in the bond length, provides fixity via grout to the surrounding rock.
Heavy duty corrugated polyethylene sheathing in the bond zone and smooth sheathing over the free length form a flexible, but impermeable membrane to protect the strand tendon against corrosion over its 100+ year design life.

ANCHOR FABRICATION

The anchors were fabricated at site on a specialist bed, using a purpose-built strand pusher and greasing machine. This machine opens each strand, separating the individual seven wires, fully greases each wire, then reforms the strand and pushes it into the 20mm HDPE sleeve.
After fabrication, the anchors were transferred into a storage rack. Sheath for the main tendon, was prefabricated as a complete unit with spacers and grout tubes, prior to installation into the dam by crane.

INSTALLATION & TESTING

The anchors were individually loaded and transported on a specially designed trolley system and installed into pre-drilled holes in the dam crest, through into the underlying bedrock. This was followed by a meticulous grouting process with 0.36w/c ratio Oilwell cement grout. After the grout had achieved strength and an age of 21 days, anchors were stressed to their test and lock-off loads using a 1,250t capacity hydraulic jack. Each anchor's residual load was checked a minimum of 48 hours after stressing to verify the residual load. Upon confirmation of the correct loading, the tendons were trimmed, corrosion protected and fully capped.

TRUNNION TENDONS

Initially the trunnion tendons were detailed in 75mm bar but, due to installation difficulties, an alternative was proposed to convert the tendons from bar to strand. The works were spread over two piers, each with 4-26 15.2mm diameter tendons, and two abutments with 2-26 15.2mm diameter and 1-31 15.2mm diameter tendons.
At the piers which were newly constructed, heavy duty HDPE pipes were cast in during forming. A small window was left at the base to allow fitting of the four dead end anchorages and, at the top, the trunnion mounting incorporated provision for the stressing tendon anchorages. The existing abutments required careful drilling from the top to intersect the lower anchorage location, which was excavated into the side of the abutment. HDPE pipe was then installed and later grouted. Thorough detailing was necessary in order to maintain the corrosion protection systems.

Project statistics

Permanent Anchors	**9 – 50 x ø15.2mm strands**
◆ Vertical anchors	48 or 54m long each
◆ Bond length	11m each
◆ Drill hole size	ø310
◆ Minimum breaking load	12,500kN
◆ Test force	9,750kN (78% MBL)
◆ Lock off load	8,750kN (70% MBL)
◆ Design working load	7,500kN (60% MBL)
◆ Strands	25t
◆ Class G Oilwell cement	50t
Trunnion Tendons	**12 – 26 x ø15.2mm strands** **2 – 31 x ø15.2mm strands**
◆ Inclined tendons	16.4m long each
◆ Minimum breaking load	6,500kN / 7,750kN
◆ Maximum design load	4,550kN / 5,425kN (70% MBL)
◆ Capacity after losses	4,160kN / 4,960kN (64% MBL)
◆ Strands	7t
◆ Class G Oilwell cement	4t
◆ Multi anchorages each end of the tendon	
◆ Drill hole size	ø165 / ø175
◆ HDPE sheath size	ø160

UPGRADING **dam safety**

MAJOR FLOOD

Works commenced in December 2006 – and were two days from completion, when a 4m high major flood engulfed the site. It was six weeks before we could gain access to the work area again and unfortunately the stressed, but ungrouted abutment tendons were damaged by corrosion and required replacement which we completed in May 2007.
The flood event loaded and submerged the permanent anchors, demonstrating their effectiveness in providing additional stability to the dam. On close inspection the anchorage zones were 100% dry, even after being submerged for a significant time, confirming their reliability, the quality of the system and the workmanship of the team.

QUEEN'S WHARF MAINTENANCE REPAIRS, LAUTOKA, FIJI

Keeping Fijian trade **afloat**

BBR CONTECH's experience and capabilities in concrete repair have recently been applied to a year-long project in Fiji in joint venture with Downer EDI Works – at Queen's Wharf in Lautoka.

The Wharf is the hub of western Viti Levu's shipping trade, an entry point for naval ships, yachts, cruise ships and cargo vessels – and an exit point for Fiji's export trade.

HISTORY

The Wharf was built in the 1960s and remained in full use until the 1980s, when the underside reinforced concrete elements began to show signs of severe deterioration. In 1990, a joint venture between BBR Contech and McConnell Dowell undertook a two-year project to rehabilitate the substructure and topside elements – and three years ago, the Wharf was extended and upgraded to allow for increased import and export trade.

While the 1990 repairs are still in very good condition, project consultant Sinclair Knight Merz identified increasing signs of deterioration in the concrete beams and deck elements of the original wharf.

SUITABLE SOLUTION

To remedy the situation, in July 2006 BBR Contech and joint venture partner Downer EDI Works launched a project to cut out the defective concrete, clean and repair corroding reinforcing steel and reinstate with new concrete. With a requirement to ensure the port remained operational throughout, the project was conducted in stages, with only small areas being worked on at any one time.

A unique combination of BBR Contech expertise and local hands-on experience from Downer led to a solution that matched the Fiji environment, as well as the Wharf's operating conditions. Extensive analysis, development and testing – in both New Zealand and Fiji – resulted in a marine-grade mix of self-compacting and dry-spray (gunite) concrete made from local aggregate that was well-suited to the tropical conditions and tidal environment. In addition, it was easy to use and apply using dry-spray techniques.

HYDRO-DEMOLITION SAVINGS

With the help of a workforce of 50 local tradespeople, the defective concrete was demolished and the corroded steel cleaned using "hydro-demolition" – a new, ultra-high pressure (40,000psi) water-blasting system mounted on huge truck rigs that saved not only time and jack-hammer equipment, but also the cost of employing an additional 30-40 people to do the work. The concrete mix (about 700m^3) was then sprayed onto the new surface.

In total, the team completed 750m^2 of beam repairs and 2000m^2 of deck soffit repairs, broke out and rebuilt 114 shear walls and replaced 650m^2 of deck. Given the heat and the gruelling working conditions, it's an impressive achievement!

Constructed in 1981 and extended in 1994, the Hastings District Council wastewater facility screens and discharges wastewater from domestic and trade flows for the greater Hastings District.

A 2004 report by Opus International Consultants found that the acid producing aerobic bacteria – which thrive in high concentrations of hydrogen sulphide gas – had caused severe biological attack of the concrete (biogenic corrosion). Up to 50mm of concrete loss was observed in some locations and the reinforcing bars were under threat from corrosion caused by acid attack.

Opus evaluated the potential product options for remedial works to the facility and concluded that the special mortar, a 100% calcium aluminate concrete, was the most suitable product given the various limitations for this application.

The product meets the primary objectives of the project:

- It provided the replacement concrete that had been eroded away.
- It has a level of protection against biogenic corrosion at least eight times that of OPC mortar.
- It can tolerate both moisture on the substrate – and sewage flows – a short time after application.
- The material is machine-applied by the dry "gunite" technique, ideally suited to easy delivery to the work

High performance **concrete**

WASTEWATER REHABILITATION, HASTINGS, NEW ZEALAND

face. In addition, it is quick to apply and the technique provides high levels of compaction at a low water-to-cement ratio.

- Compared to any of the two coat systems requiring both concrete filler and an overcoat, it was a very effective and economical solution.

BBR Contech was awarded a contract to supply and install the special mortar for the remediation project and commenced work on site in mid-January 2007 for what is thought to be the largest rehabilitation of a live wastewater treatment plant ever carried out in New Zealand.

As with any concrete remedial works, the secret of successful application is dependent on the quality of the surface preparation and the removal of the contaminated concrete from the surface. With experience, the contractor has found that the only really effective method to remove this contaminated concrete – and prepare the surface to a suitable profile for application of the special mortar – is to use ultra-high pressure, low volume (UHPLV) water-jetting. The added bonus of this method of preparation is that it very effectively cleans and prepares for coating any exposed reinforcing bars within affected areas of the concrete.

With the limited access points and requirement to place the materials quickly before the flows rose again the next day, the dry-spray application technique (guniting) proved invaluable. On occasions when the flows in the structures rose rapidly, the special mortar remained fully bonded to the substrate, despite the submersion only hours after application. Random pull-off tests conducted to check the bond characteristics of the new mortar to the prepared substrate demonstrated that bond strengths exceeding 1MPa were consistently achieved.

Over a period of eight weeks, some 570m^2 of concrete was prepared and 14m^3 of the special mortar was applied to the various structures in the plant.

This contract was carried out in the most difficult and challenging conditions that a fully operational wastewater facility can present. The skills, perseverance and teamwork of the contractor, sub-contractors, plant operators and consultants all contributed to bring about a successful result for Hastings District Council.

FACTORS & CONSTRAINTS

The Opus report identified the following factors and constraints which would need to be considered for a remedial solution in order to satisfy the Council's objective of extending the useful life of the structures in the plant:

- With very little opportunity available to isolate the various structures through by-pass pumping, the plant would need to remain fully operational during the remedial works. Repairs would have to be able to be completed in a live sewer.
- The system used to remediate the corroded concrete would need to provide both a rebuild of the already corroded concrete and provide superior resistance to future further breakdown than was exhibited by the Ordinary Portland Cement (OPC) concrete that was used in the original construction.
- For the majority of structures associated with the treatment plant, the repairs would need to be carried out in a six week window of opportunity prior to some peak flows of trade waste produced by the local food canning industry.
- Many of the structures had repairs extending right down to the level of the sewage and, in some cases, the repairs would be covered with sewage only hours after application of the repair materials.
- Relatively large quantities of repairs would be required for some structures and this called for an application method which could provide ease of delivery and effective application of the materials onto the structure.

BEARING REPLACEMENT, MORSHEAD OVERPASS, MELBOURNE, AUSTRALIA

Benchmark bridge

Morshead Overpass located in Melbourne, Australia was built in 1963 and widened in 1999. Since its construction, the overpass has been exposed to steadily increasing traffic numbers and far heavier vehicle loads than its designers could have anticipated. The bearings beneath the bridge had not only reached the end of their operational life, reports Jason Xerri of **Structural Systems Limited,** but they had experienced loads well in excess of their initial design.

Structural Systems Limited was awarded the bearing replacement project, which involved replacing 20 elastomeric bearings and 14 mechanical bearings over four piers. These new bearings have been designed for T44/L44 loading, in order to satisfy the Austroads bridge design code.
In order to replace all of the elastomeric and mechanical bearings successfully, a replacement procedure for each type of bearing was specifically designed. Each individual bearing and its location presented its own special design challenges for the contractor.

ELASTOMERIC CHALLENGE

The elastomeric bearings which support the main concrete girders of the overpass are, in turn, supported by a corbel attached to the main crosshead. The difficulty here was that the girders could not be jacked up from the crosshead as there was minimal space in which to work. The corbel could not be used either, as it was unable to support the loads imposed by the jacks.
Structural Systems, in conjunction with Maunsell Australia, provided road operator CityLink with an innovative solution. The lifting jacks were seated on prefabricated steel angle brackets which were fixed to the edge of the corbel using 40mm stress bars. The bars were cored through both the pier corbel and crosshead. This method created a sturdy, spacious and fully adjustable lifting platform and not only provided permanent strengthening to the corbel, but the stress bars can also be utilised for future bearing replacement activities as this system was unbonded.

MECHANICAL BEARINGS

The mechanical bearings assist in supporting the main steel girders of the overpass which are, in turn, supported by concrete crossheads. The replacement method here was much simpler, in terms of jacking, as there was enough space on the crosshead to seat the jack behind the existing bearing.
The bearings were fixed by weld to both a bottom and a top plate. The bottom plate was fixed to the crosshead and the top plate was welded to the steel girder above. All of the welding was done once the bearing was in position during the jacking procedure, as the exact alignment of the crosshead exit holes could not be accurately located until the existing bearing was removed.

UNIQUE PROJECT

This project was unique for Structural Systems in the sense that we worked directly for the Principal and undertook the project as the main contractor. Structural System's expertise and experience in this field provided an efficient

execution of the project and all parties were extremely satisfied with the outcome. This project has also provided the benchmark for bridge bearing replacement projects – featuring innovative solutions and a professional approach to ensure the works were carried out safely and in a timely manner.

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OWNER
Citylink Melbourne Limited

CONTRACTOR
Structural Systems (Southern) Pty Ltd

DESIGNER
Maunsell Australia

TECHNOLOGY
Bearings

BBR NETWORK MEMBER
Structural Systems Limited (Australia)

Photographs courtesy of Roland Halbe, Stuttgart

BERGISEL SKI JUMP, INNSBRUCK, AUSTRIA

Jewel of the Austrian Alps

The ski jump on Bergisel – one of the mountains which surround Innsbruck – is the third station of the annual Four Hills Ski-Jumping competition. This iconic structure – the jewel in the Tyrolean capital's crown – owes its reality, not only to a visionary architect, but also to excellence in construction engineering.

→

For the 1976 Olympic Games, a post-tensioned structure was built for the in-run of the jump, utilising VT tendons recalls Rudolf Vierthaler of Austrian BBR Network member, **VORSPANN-TECHNIK (VT).**

With the constant evolution of the techniques involved in the sport of ski-jumping, the configuration of the Bergisel structure no longer met the international standards required by the sport's governing body – the Fédération Internationale du Ski (FIS) – and was replaced by a new structure in 2002 and, again, a post-tensioned solution has helped to create a masterpiece of design.

World famous architect, Zaha Hadid won the international competition, in 1999, with a design that reflects the dynamics of this sport in a truly breath-taking way.

STRUCTURAL CONCEPT

The structure consists of the foundation platform, the tower, the tower head and the in-run. The 16m by 20m foundations contain floors which accommodate technical equipment, storage facilities and offices, as well as the entrance level to the elevator. The 48.5m high elevator tower is a hollow-box with 40cm thick concrete walls. The tower head is a three floor steel frame structure, weighing 90t, which cantilevers up to 12m from the tower shaft. The basic concept for the in-run was a four-span continuous beam with three piers. Finally, the in-run was completed with a single span of 70m in length and an inclination of 35 degrees. The structure is a composite trough section of steel frames and a concrete slab – with external tendons below, supported in the form of a "fish belly", by triangular shaped distance members.

Post-tensioning was applied for fastening of the tower head steel structure to the concrete shaft and for the external tendons to the in-run bridge.

FIXING THE TOWER HEAD

A system of steel consoles was developed for the connection of the steel structure to the concrete tower. These consoles – the heaviest of which weighed-in at 550kg – had to be integrated into the climbing form for the tower to an accuracy of 1cm. After finishing the concrete works for the shaft, the consoles were stressed against the tower and grouted. The steel frames of the tower head were plugged onto the consoles and fixed in position by welding.

Transversal bonded tendons through the walls between the consoles managed the introduction of the forces to the concrete. Dependent upon the forces that had to be introduced, these tendons were of 6, 12 or 16 strands.

IN-RUN EXTERNAL TENDONS

In the early detail design phase, five closed ropes were considered for the external tendons. Following an alternative proposal by VT, strand tendons were selected for the task. The tendons are composed of $150mm^2$ galvanised strand inside a wax-filled HDPE-duct. The tendons were prefabricated in VT's factory, then transported to the site in reelless coils and installed using winches.

The stressing forces were applied in two stages – the first stage after assembling the steel structure and the second stage after concreting the slab for the in-run track.
Post-tensioning was an appropriate technology for the realisation of the architect's vision. The first competition on the new jump took place in January 2003 and, ever since then, the building has been a major landmark of Innsbruck.

TEAM & TECHNOLOGY

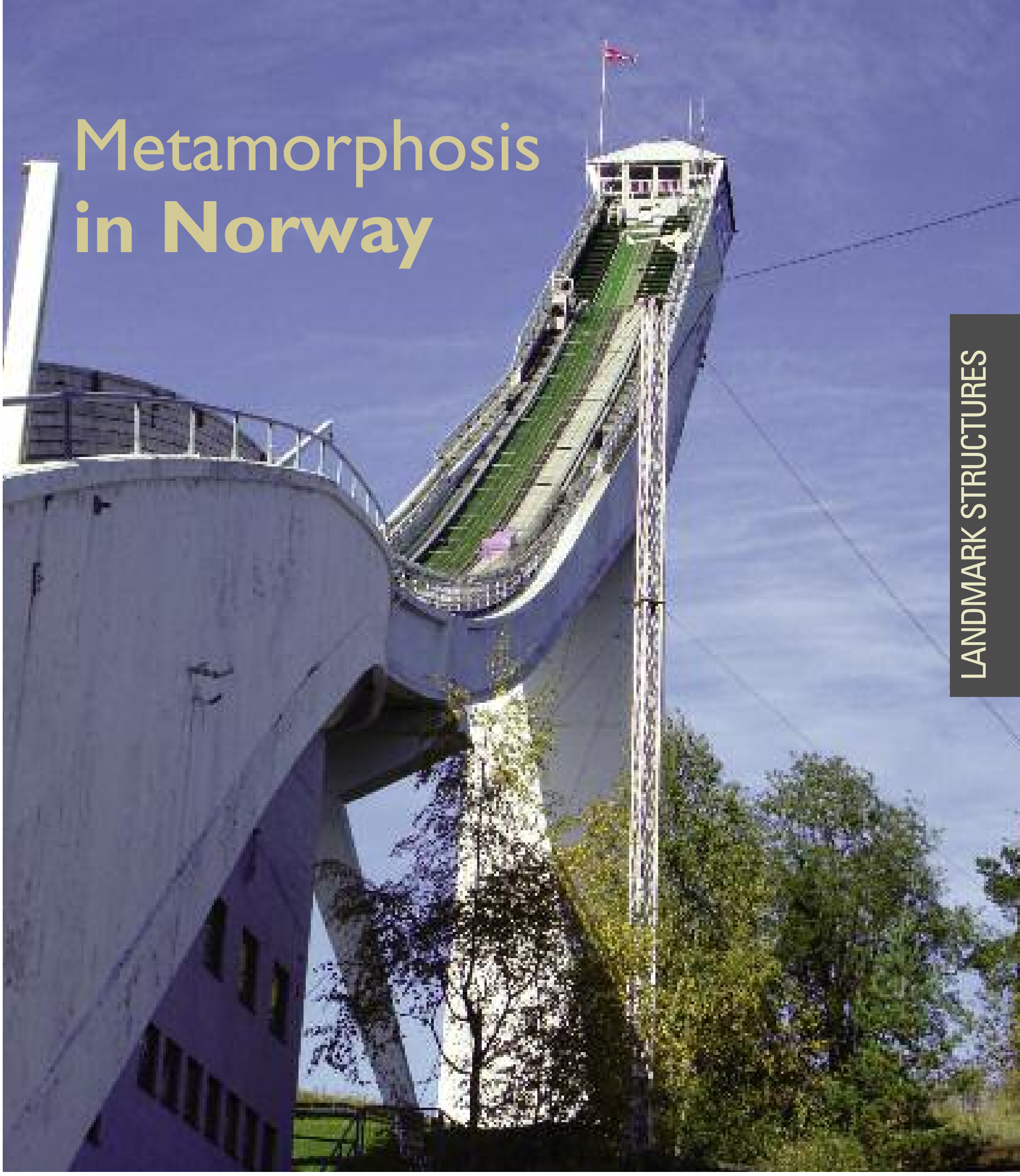
OWNER
Bergisel Betriebs GmbH

CONTRACTOR
JV Alpine-Mayreder / Ast-Holzmann (concrete)
Stahlbau Pichler GmbH (steel)

ARCHITECT
Zaha Hadid, Jan Huebener
Structural Engineers
Christian Aste, Andreas Glatzl, Gerald Huber

BBR NETWORK MEMBER
VORSPANN-TECHNIK GmbH & Co. KG (Austria)

Metamorphosis in Norway



HOLMENKOLLEN SKI-JUMP, OSLO, NORWAY

Holmenkollbakken, the ski-jump at Holmenkollen – located on the hill of the same name in Oslo – is the venue for one of the world's oldest ski-jumping competitions and, over the years, the jump has been rebuilt or altered 18 times. Now, as Norway prepares to host the 2011 FIS Nordic World Ski Championships, the ski-jump is about to be reborn yet again.

It all started in 1892, when 10,000 people came to watch the first competition at Holmenkollen – since then, crowds have grown to over 100,000 spectators. Ski-ing has truly been the "sport of kings" in Norway, with Crown Prince Olav taking part in competitions in 1922 and 1923 and the current royal family always present for the Holmenkolldagen – the national ski-jumping day.
Although the current ski-jump was constructed in 1939, it has seen many modifications since then – most of the upgrades were carried out for the 1952 Winter Olympics. The opening of a restaurant in the tower – making Holmenkollbakken a meeting place for the summer months too – followed shortly afterwards.
However, for the 1966 World Championships, an extension was needed to the actual ski-jump structure – the plan was to extend its height by adding a concrete lip. This was to be built using the free cantilever method and, in order to handle the stresses and forces, a post-tensioned solution was chosen using vertical BBRV tendons installed by BBR Network member Spennteanikk. Subsequent alterations have included modifications to the outrun, but soon Holmenkollen is to have a completely new ski-jump. Given the importance placed upon skiing in the Norwegian culture, the process of choosing a replacement structure has caused much debate and, indeed, controversy. A stunning design by a Danish architect has been chosen – the "Tower of Light" is set to make a dramatic entrance to the Norwegian landscape.

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